THE UNIVERSITY OF TEXAS BULLETIN

No. 3601: January 1, 1936

THE VAN OIL FIELD, VAN ZANDT COUNTY, TEXAS

By

RALPH ALEXANDER LIDDLE

Bureau of Economic Geology
E. H. Sellards, Director

PUBLISHED BY
THE UNIVERSITY OF TEXAS
AUSTIN

THE UNIVERSITY OF TEXAS

THE W. S. ADKINS
COLLECTION

care of the bureau or division issuing the bulletin: Bureau of Business Research, Bureau of Economic Geology, Bureau of Engineering Research, Bureau of Industrial Chemistry, Bureau of Public School Interests, and Division of Extension. Communications concerning all other publications of the University should be addressed to University Publications, The University of Texas, Austin.

Additional copies of this publication may be procured from the Bureau of Economic Geology, The University of Texas, Austin, Texas

THE UNIVERSITY OF TEXAS PRESS

THE UNIVERSITY OF TEXAS BULLETIN
No. 3601: January 1, 1936

THE VAN OIL FIELD, VAN ZANDT COUNTY, TEXAS

By

RALPH ALEXANDER LIDDLE

Bureau of Economic Geology
E. H. Sellards, Director

Published in part from the Fort Worth Geological Society
Revolving Publication Fund of The
University of Texas

PUBLISHED BY THE UNIVERSITY FOUR TIMES A MONTH AND ENTERED AS
SECOND-CLASS MATTER AT THE POSTOFFICE AT AUSTIN, TEXAS,
UNDER THE ACT OF AUGUST 24, 1912

The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of Democracy, and while guided and controlled by virtue, the noblest attribute of man. It is the only dictator that freemen acknowledge and the only security which freemen desire.

Mirabeau B. Lamar

CONTENTS

ILLUSTRATIONS

Plates 2–27 in pocket

PREFACE

Commercial production of oil and gas was found in the Van field, Van Zandt County, Texas, on October 13, 1929. Mr. R. W. McIlvain, Vice-President of The Pure Oil Company, outlined immediately thereafter a unit plan of development to the companies holding leases within the area believed to be productive, suggesting that this area be unitized and operated as if under single ownership. The Van Joint Account was perfected on November 1, 1929, and since that time all leases within the unitized area have been developed and operated by The Pure Oil Company for the account of the associated companies. This efficiency has permitted maximum recovery of oil and gas at minimum cost.

Mr. Theron Wasson, Chief Geologist of The Pure Oil Company, outlined a method of valuing individual leases for the preliminary evaluation, two and a half years after the plan was inaugurated, and for the final evaluation at the end of the first five-year period from the inception of the agreement. The individual leases were valued on the basis of their contained acre-feet of Woodbine formation. This method was adopted and excellent results were obtained.

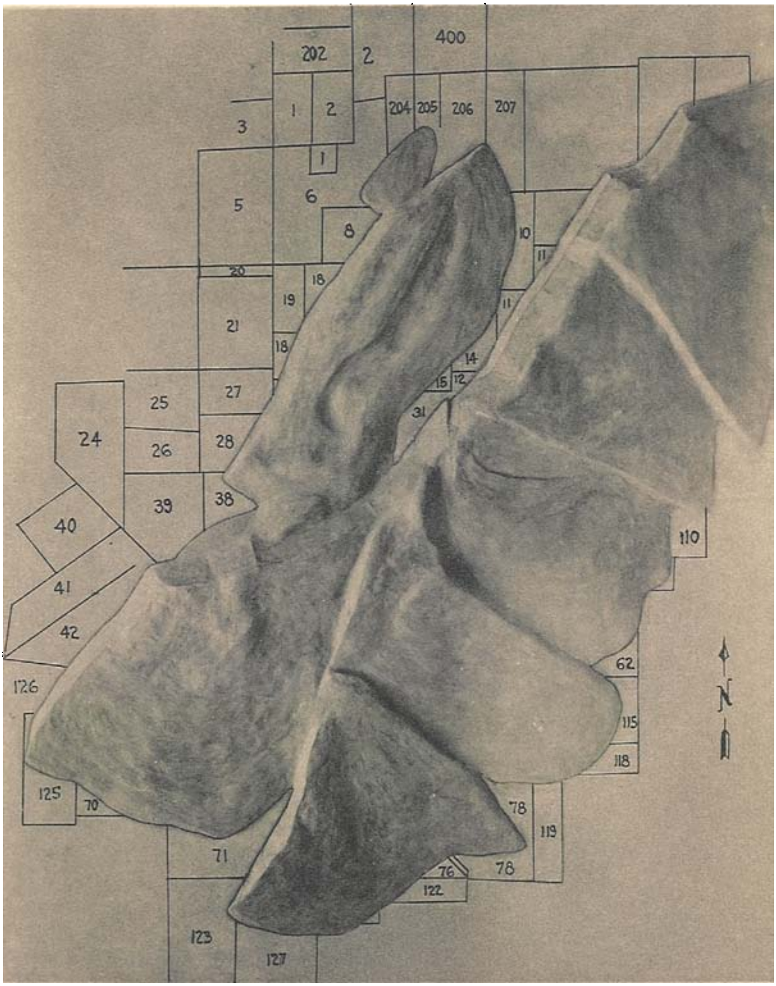
The Pure Oil Company, Shell Petroleum Corporation, The Texas Company, Sun Oil Company, and the Humble Oil and Refining Company are participants in the unitized Van Joint Account and have coöperated to the fullest extent to make the unit development an outstanding success. To them I express my appreciation for their courtesy in permitting this publication.

Two of the maps (Pls. 21 and 22) presented in this work were prepared by geologists of the associated companies, at the time of the final valuation. Mr. E. M. Rice has supervised the geological work in the Van Joint Account since the discovery well was drilled, and Mr. J. S. Locke has done similar geologic work in the Carroll district. To both I am deeply indebted for the use of their accurate records and intimate knowledge of structural conditions in the field. Mr. F. E. Poulsen has kindly checked the maps, and Mr. N. L. Thomas has read the text. Their criticism has greatly improved the accuracy of this work. Miss Charlotte Andrews and Miss Nellie Jefferson have helped in the typing of the text and in the preparation of the maps. Mr. A. R. McElreath and Mr. F. W. Suggett have

generously afforded me the facilities of their office. Dr. H. B. Stenzel has read the entire manuscript and has greatly improved it by his suggestions.

Finally for the tedious labor of checking map data against original field records, I am indebted to Mrs. R. A. Liddle.

RALPH ALEXANDER LIDDLE
FORT WORTH, TEXAS
OCTOBER 13, 1935



Photograph of a model of the Woodbine formation in the Van oil field. The model shows that part of the Woodbine formation in this field which lies above an elevation of —2500 feet sea level datum. Comanche is exposed below the Woodbine in the fault face in the northeastern part of the field. Horizontal and vertical scales are 1 inch equals 4500 feet. Model constructed by Isabel B. Wasson and Theron Wasson. Photograph by N. L. Thomas. Land tract numbers included so as to aid in the location of structural features. The major fault of the field trends northeast-southwest with minor faults approximately at right angles to the major fault.

THE VAN OIL FIELD, VAN ZANDT COUNTY, TEXAS

RALPH ALEXANDER LIDDLE[1]

INTRODUCTION

In the eastern part of the State of Texas great masses of rock salt have risen from unknown depth and source, some penetrating thousands of feet of sediments to reach the surface, others stopping on the way. The Van oil field is located on the top of a domed uplift, which is believed to be underlain at profound depth by an enormous salt mass. The salt mass has elevated the overlying rocks half a mile above their normal level and has disturbed an area of 500 square miles. A study of the geology of this oil field reveals some of the genetic history of an incipient deeply buried interior salt dome and the accumulation of a major oil field on it.

The Van oil field is primarily a geological discovery, supplemented by geophysical investigation and core drill exploration. Each type of work contributed its evidence, but the presence of commercial production was not established until the discovery well, Jarman 37 No. 1, flowed oil and gas from the Woodbine formation on October 13, 1929.

EAST TEXAS EMBAYMENT

REGIONAL STRATIGRAPHY AND STRUCTURE

Cretaceous and Eocene sediments dip eastward from the Bend arch, southward from the Arbuckle and Ouachita mountains, and westward from the Sabine uplift toward the axis of a great embayment which embraces the northeastern part of the State of Texas.

Along the western and northern sides of the embayment there is evidence of the base on which the Lower Cretaceous rocks rest. At Luling in Caldwell County schistose rocks[2] of probable pre-Cambrian age lie directly beneath the Lower Cretaceous beds and

---

[1]Chief Geologist, Texas Producing Division, The Pure Oil Company.

[2]Brucks, E. W., The Luling field, Caldwell and Guadalupe counties, Texas: Bull. Amer. Assoc. Petr. Geol., vol. 9, pp. 632–654, 1925.

have been penetrated to a depth of 3131 feet.[3] Farther northeast, and along the Balcones fault zone, several Paleozoic horizons have been identified, either definitely or provisionally.[4] These range in age from questionable Ordovician to fairly definite Pennsylvanian. Beds which resemble the Pennsylvanian have been reached directly below the Lower Cretaceous in a few deep wells in Tarrant and Dallas counties. West of the Balcones fault zone the Lower Cretaceous beds overlap and are in direct normal contact with the Pennsylvanian. The Permian first appears on the west flank of the Bend arch.

On the north flank of the East Texas embayment, surface outcrops in Oklahoma show that the Cretaceous laps unconformably over various Paleozoic formations—the youngest being Pennsylvanian in age. Wells in Montague, Cooke, Grayson, Fannin, Lamar, and Red River counties, Texas, also have found Pennsylvanian directly beneath the Cretaceous, but nowhere is there definite evidence of Permian, Triassic, or Jurassic. Therefore, judging from surface outcrops on the west and north flanks of the basin, and from information obtained through wells drilled, there is little reason to assume the presence of Permian, Triassic, or Jurassic rocks beneath the Lower Cretaceous in the East Texas embayment. Emphasis is placed here on the probable absence of these rocks under the East Texas embayment because of the bearing this fact has on the age and source of salt which forms the core of many salt domes and domed structures not only in the East Texas embayment but in a similar embayment in Louisiana, that extends northward into Arkansas.

At the east side of the East Texas embayment is the great Sabine uplift which exposes Eocene (Wilcox) beds over much of its surface extent. Wells located on it have not drilled through the Lower Cretaceous, and consequently there is no positive information about the underlying rocks. In the center of the East Texas embayment and southward, the deepest well has penetrated only a part of the first thick sandstone horizon below the Glen Rose, doubtless (as has

---

[3]Sellards, E. H., Rocks underlying Cretaceous in Balcones fault zone of central Texas: Bull. Amer. Assoc. Petr. Geol., vol. 15, pp. 819–827, 1931.

[4]Miser, H. D., and Sellards, E. H., Pre-Cretaceous rocks found in wells in Gulf Coastal Plain south of Ouachita Mountains: Bull. Amer. Assoc. Petr. Geol., vol. 15, pp. 801–818, 1931.

been learned from drilling at Pine Island[5] and at Bellevue,[6] in Louisiana) leaving several thousand feet of Lower Cretaceous section unpenetrated.

PHYSIOGRAPHIC EXPRESSION

The Van dome is situated near the headwaters of Neches River and forms a topographic divide separating drainage into Sabine River from drainage into Neches River.

TOPOGRAPHY AND DRAINAGE

The Van dome is located in gently rolling terrain formed by the breaking down of sands and clays of the Wilcox formation. As these beds are rather uniform in resistance, no marked topographic features have developed in the Wilcox outcrop. Much of the Wilcox outcrop on the dome is covered by loose grayish-white sand which in places after rains becomes quicksand. Gray, drab, and brownish shales are found in some freshly cut gully walls but they soon become covered with loose sand or soil. Drainage features in the Wilcox area are usually shallow and choked with sand, especially near the top of the uplift.

A rim of Reklaw greensand flanks the Van dome on the south, east, and northeast. The Reklaw formation weathers to a deep-red, ferruginous sandstone and finally disintegrates to deep-red soil. In places this iron-cemented sandstone forms a ridge, though it occurs only intermittently in a band around the flank of the structure, outcropping outside the Wilcox. Outside the Reklaw and overlying it are soft shales and sandstones of the Queen City formation in turn flanked by heavy beds of the Weches formation which is a resistant greensand and forms prominent hills. Westward from the top of the Van structure the terrain overlying the Wilcox formation continues with little variation in character.

As the Wilcox formation on the top of the Van uplift is relatively soft and uniform in resistance, the surface rocks influence drainage very little. Consequently the radial drainage pattern developed

---

[5]Crider, A. F., Pine Island deep sands, Caddo Parish, Louisiana, *in* Structure of Typical American Oil Fields, vol. 2, pp. 168–182, Amer. Assoc. Petr. Geol., 1929.

Teas, L. P., Bellevue oil field, Bossier Parish, Louisiana, *in* Structure of Typical American Oil Fields, vol. 2, pp. 229–253, 1929.

[6]Fletcher, C. D., Structure of Caddo field, Caddo Parish, Louisiana, *in* Structure of Typical American Oil Fields, vol. 2, pp. 183–195, 1929.

indicates the top of the uplift. Further surface indication of the Van uplift is found in the scarcity and unpalatable nature of water on the top of the dome, whereas abundant good drinking water is obtained in the same formation (Wilcox) on the flanks of the uplift.

REFRACTION SEISMOGRAPH SURVEY OF THE VAN AREA

A seismograph reconnaissance of the refraction type in the Van area was begun May 5, 1927, to check the significance of erratic dips, surface faulting, abnormal drainage, and topography. After many interruptions the survey was completed June 24, 1927.

Approach to the Van area was from the southeast up the Neches River valley, and the first indications of abnormal subsurface conditions were irregularities in refraction records suggesting an upward slope or rise toward the northwest in the Pecan Gap and Austin formations. This was followed northward through Ben Wheeler and Van to Pruitt. Though the "leads" on the records were too small to indicate that a salt mass was being refracted, they did show an abnormal uplift of the Pecan Gap chalk amounting to at least 300 feet. An attempt was made to detail the top of the structure, but uniform records could not be obtained probably because the surface of the Pecan Gap is irregular due to faulting. Short profiles were tried but without success, and then long profiles were used. A depth calculation of F.P. No. 11,[7] which is located in the western part of the area surveyed, placed the Pecan Gap at 1850 feet below the surface, whereas a depth calculation at F.P. No. 10 showed the same horizon to be only 1550 feet below the surface. At that time the depths were only considered to be relative —not absolute—but later information confirmed their accuracy for actual depths. Profile 26-A which runs east and west just north of Van showed an abnormally high velocity, doubtless due to shooting up dip on the structure, as was suggested at the time. The general outline and contour of the uplift were found by "fanning" outward from the apex until no further irregularities were encountered. The survey indicated the structure had a north-south extent of about 8 miles and an east-west extent of more than 5 miles.

A copy of the original refraction map is included (Pl. 4) because of its historical interest.

[7]The abbreviation F.P. used in this paper stands for firing point.

TORSION BALANCE SURVEY OF THE VAN AREA

Torsion balance traverses of a reconnaissance type were run in a radial manner from the center of the Van uplift to ascertain if gravity on the Van structure differs from gravity of the surrounding area. None of the lines was extended far enough from the top of the dome to reach the outer limit of the area involved in the Van uplift, but, notwithstanding, definite evidence was obtained (Pls. 5 and 6).

Study of torsion balance data indicates that a large deeply seated mass of lower specific gravity than the surrounding sedimentary rocks underlies the Van structure and is coincident with the uplift in the formations penetrated by drilling. In all probability a mass of salt underlies the Van dome at great depth. Magnetic and gravity surveys as well as data from drilling indicate that the longer axis of the uplifted area runs in a north-south direction, though this axis is modified by faulting to a northeast-southwest direction.

Over the top of the Van dome the Wilcox formation breaks down into fairly smooth terrain which is conducive to uniformity in curvature values. On the flanks the terrain is rugged, and many erratic gradients had to be discarded. Curvature values in such areas are also influenced too much by surface irregularities and were of no assistance in the interpretation. The gravity survey shows that basically the gravity increases to the west and northwest. The increase is due to a gentle but gradual rise of the formations from the axis of the East Texas embayment toward their outcrops.

In order to show the gravity conditions of the Van area more clearly, the regional gravity effect was calculated and subtracted from the gradient values. This regional gravity effect was found to be 5.1 Eötvös units north and 1.3 Eötvös units west. The regionally corrected isogams were calculated and plotted on the accompanying gradient map (Pl. 6) at an interval of 0.5×10^{-3} C.G.S. units. These isogams show clearly a gravity minimum corresponding with the Van uplift and indicate the approximate center and form of the mass of low specific gravity which lies beneath and is thought to be responsible for the uplift. Because of the reconnaissance nature of the survey no attempt was made to locate faulting, though it is evident where crossed by traverses. The main fault, which is upthrown on the southeast side and crosses the dome in a northeast-southwest direction, is indicated by small and reversed gradients such as those obtained at stations 310, 311, 312, 191, 343, and 192 (Pls. 5 and 6).

Locally on the flanks of the Van uplift where the terrain is rugged, the gravity values are erratic and do not represent true subterranean anomalies, as the surface effect cannot be removed entirely. In calculating the isogams, therefore, a few values were disregarded. Furthermore, with only two intersecting traverses, it is impossible to calculate the true regional gradient, which is an essential if a correct gravity picture is to be obtained of the minimum, as a small variation in the regional effect will shift its center and outline. The center of the minimum delineated by isogam I (Pl. 5) is somewhat displaced from the center of the structure as known from drilling. The absence of closure on the southeast flank is due to insufficient observations and the character of the terrain which rendered some station values useless. However, when the regional gravity effect is removed, a better closure is obtained on the southeast flank, and the center of the minimum, outlined by isogam 0 (Pl. 6), corresponds favorably with the apex of the dome as delineated by subsurface data from drilling.

Over 3000 feet of fairly steep south and southeast dip is known to exist in the Woodbine formation on the Van dome, and consequently there is little doubt but that ample closure would have been developed by adequate torsion balance traverses on this flank.

An attempt was made to delineate the slope of the mass that produces the gravity minimum. This mass lies beneath the sedimentary rocks and is probably composed of rock salt. Delta gamma curves were calculated (Pl. 7). These curves are rather irregular on account of erratic gradient values caused by surface irregularities, such as broken terrain and local outcropping beds of thick or hard sandstone. Notwithstanding these features, the curves change distinctly in a fashion which is characteristic of the shape of the mass of low specific gravity that lies probably below the Comanche. A sharp drop on the flank of the dome occurs between the stations 366–368, 334–335, 313–189, 344–346, and 266–267. A line connecting these points marks the first bench on the flank of the mass of low specific gravity. Theoretically the gradient values should decrease beyond these points if the edge of the mass of low specific gravity plunges rapidly downward beyond this bench. Study shows, however, that the gradients increase again beyond the bench. This increase can be explained only by assuming that there is another and probably more profound drop at the points where the maximum gradients are found. Between stations 373–374, 181–182, 323–324, 353–355, and 361–362 occur maximum gradients, and a line connecting these points outlines the second sharp drop or bench outward from which the mass of low specific gravity plunges to great depth.

For contrast with the results of the gravity survey of the Van dome, a torsion balance traverse was run across the Grand Saline salt dome where the salt stock is roughly a mile in diameter and lies within a few hundred feet of the surface. The Grand Saline salt dome is very clearly reflected by the gradient curve especially when the regional effect, amounting to 5 Eötvös units, is taken into consideration. The center of the gravity minimum is between stations 166 and 167. The large gradients obtained at stations 163 and 177 may be due to a bed of high density occurring close to the surface (Pls. 5 and 6).

MAGNETIC SURVEY OF THE VAN AREA

Magnetic studies of the Grand Saline and Haynesville salt domes, adjacent to the Van structure, have afforded interesting data which have been compared with the results of a magnetic survey of the Van area (Pl. 7). At Grand Saline and at Haynesville no local magnetic reaction or abnormality has been found; at Van there is a definite minimum of small intensity which is located approximately at the top of the structure. Grand Saline and Haynesville are domes in which the salt stocks have diameters of about a mile and lie within a few hundred feet of the surface, whereas the Van oil field is on top of an uplift in which the salt mass believed to be present has a diameter of 10 miles or more and doubtless lies from 10,000 to 15,000 feet below the surface. These observations suggest that to be recognizable in a magnetic survey, salt domes must have great mass. Sedimentary rocks of the character of those comprising the east Texas region have low magnetic intensity and slight variation; consequently only a large salt mass can give variation sufficient to be mappable.

Similar conditions have been observed near some basic igneous intrusions. Mass is an important component of igneous plugs, if they are to be located readily in magnetic surveys.[8]

HISTORY OF THE DISCOVERY OF THE VAN OIL FIELD

On January 22, 1927, 8 feet of oil-saturated sand was penetrated in Humble Oil and Refining Company No. 1 Clark on Boggy Creek salt dome in Anderson and Cherokee counties, Texas. This well gauged 50 barrels of oil an hour through ¼-inch choke when placed on production a few days later. It was the first commercial production to be obtained on a salt dome in east Texas and inaugurated intensive and extensive exploration for other similar features.

Geologists of The Pure Oil Company began in February, 1927, a careful investigation of the central part of the East Texas embayment for surface indications of deeply buried salt domes. In the course of this work, the topography, drainage, erratic dips, and surface faulting in the southeastern part of Van Zandt County suggested an uplift with its highest point in the vicinity of the town of Van.[9]

In May, 1927, a seismograph party of the Geophysical Research Corporation in the employ of The Pure Oil Company was assigned to detail this area. Their work (Pl. 4) indicated a large anticline, the apex of which seemed to be just north of Van. The following mention[10] was made at the New York meeting of The American Institute of Mining and Metallurgical Engineers in February, 1928:

Van Prospect

Location.—Van Zandt County, at the town of Van.

Date of discovery.—May, 1927, by a seismograph party of the Geophysical Research Corporation, in the employ of The Pure Oil Company.

Depth to salt.—No salt records were obtained at this prospect, but there is definite uplift which has been isolated. Its character from seismograph work appears similar to the uplift at Troupe, and its

[8]Liddle R. A., Magnetometer survey of Little Fry Pan area, Uvalde and Kinney counties, Texas. Bull. Amer Assoc. Petr. Geol., vol. 14, pp. 512–513, 1930.

[9]Liddle, R. A., Van field, Van Zandt County, Texas: Bull. Amer. Assoc. Petr. Geol., vol. 13, pp 1557–1558, 1929.

[10]Liddle, R. A., Petroleum development in east Texas and along the Balcones fault zone, 1927: Amer. Inst. Min. Eng., Petroleum Dev. Tech. 1927, pp. 630–639, 1928.

location in respect to regional structural features in east Texas suggests a deeply buried dome.

Development.—There has been no drilling on this prospect.

Following the seismograph work which after interruptions terminated in July, 1927, a detailed survey of the areal and structural geology of the region was made, and it indicated (Pl. 10) that the Wilcox-Claiborne contact has abnormal exposures northeast, east, and south of the town of Van. In general it forms a crescent to the northeast, east, and south of the town instead of having its normal northeast-southwest trend. North from Sand Flat, Van Zandt County, the Reklaw greensand in the basal part of the Mount Selman formation has a northwest-southeast strike as far south as Providence School; the dip is steeply to the northeast. At Providence School the strike changes to north-south, paralleling the Van Zandt-Smith County line as far south as Galena in Smith County; the dip is steeply to the east. At Galena the strike again changes to almost east-west with a strong south dip and continues westward, passing just north of Ben Wheeler, Van Zandt County, thence west to a point north of Martin's Mills, where it swings to the southwest on its normal course. Though outcrops are meager they are satisfactory in delineating structure. To the west and northwest of the Van uplift the Reklaw is not preserved. Wilcox sands cover the entire top of the uplift. Leasing of the original block, approximately 17,000 acres, surrounding the town of Van took place in July and August, 1927.

On December 4, 1928, recommendation was made to drill two lines of core holes, one north-south and the other east-west, across the Van uplift through the town of Van, because the highest point of the structure could not be determined from surface and seismograph work, though it appeared to be at, or just north of, the town of Van.

Between January 18 and July 27, 1929, eight core tests were drilled, and information from these exploratory tests confirmed an uplift (Pl. 11) of great magnitude. In some of the core holes on top of the uplift oil and gas were encountered, the best showings being found in the sandy basal member of the Midway and in the Nacatoch sand (Upper Cretaceous)—the Nacatoch being encountered between 1100 and 1300 feet below the surface, depending on position on structure.

Location of Jarman 37 No. 1 (Pl. 27) followed a study of all available data. This well encountered many showings of oil and gas in formations between the Wilcox (Eocene) on the surface and the Woodbine (basal Upper Cretaceous) which was the objective. On October 13, 1929, Jarman 37 No. 1 was completed for an initial production of 147 barrels an hour of 35.4° A.P.I. gravity, normal Woodbine oil. The Woodbine formation was reached at 2560 feet and was penetrated to 2710 feet. Later the well was deepened.

Unitization of the various leases held by major companies on the Van uplift was perfected November 1, 1929, and development of the field proceeded in a systematic and scientific manner.

STRATIGRAPHY

SURFACE GEOLOGY

DESCRIPTION OF SURFACE FORMATIONS

EOCENE

WILCOX FORMATION

The oldest rocks exposed in the top of the Van structure are those which comprise the basal part of the Wilcox formation. They are composed of brown clays with occasional intercalated irregular layers of lignite. Occasional pieces of silicified wood lie on the surface. Grayish-white, soft, loose sands conceal the rock outcrops except in freshly scoured gully walls. Two feet of loose, powdery sand is not uncommon in places. Locally quicksand is formed when rains fall. Yellow, brown, and gray clays interbedded with the cross-bedded sandstones form a sub-soil which prevents the sand from accumulating in great depth.

From surface evidence it is impossible to ascertain how much of the Wilcox section crops out between the apex of the structure and the Reklaw greensand which overlaps the Wilcox on the south, east, and northeast flanks of the dome. Loose sand and soil form an effective cover. In addition, subdivision of the Wilcox cannot be made from surface study at Van.

Wilcox beds are found at the surface from the top of the Van dome as far west as the limit of the west flank of the structure near Canton. In the syncline immediately southeast of Canton, which limits the Van dome on the west, some geologists recognize Carrizo beds, and these beds may be preserved in this structurally low area.

CARRIZO FORMATION

It is doubtful if the Carrizo formation outcrops on the Van dome. Normally the Carrizo should lie between the Wilcox and the Reklaw and form the base of the Claiborne group. At Van, the Reklaw appears to have overlapped the beveled edges of the Carrizo and part of the Wilcox. This is not surprising in view of the several periods of uplift and erosion, as well as non-deposition, which the Van dome has experienced. Opinion differs as to the presence of Carrizo beds in the syncline which bounds the Van uplift on the west and extends from Martin's Mills to Grand Saline. It is possible that Carrizo sands are preserved in this syncline.

REKLAW FORMATION

Between 10 and 15 feet of deep red and reddish-yellow ferruginous sands, more resistant than the underlying Wilcox and overlying Queen City, form a narrow steeply dipping rim around the southeast, east, and northeast sides of the Van uplift about 3 miles distant from the apex. Outcrops of this greensand are irregular and far from satisfactory, but they are sufficient to delineate the form and suggest the magnitude of the Van structure.

QUEEN CITY FORMATION

Light-colored coarse and fine poorly consolidated irregularly bedded sands with yellow and gray shales make up the Queen City formation. The surface expression of these sands and clays is not unlike that of the Wilcox. The Queen City beds form a fairly regular terrain through which are cut some fairly deep, steep-walled gullies. Ferruginous sandstone and ironstone bands occur in the more massive gray and yellow sandstone beds where these are exposed freshly in creek banks or road cuts. Individual beds are unreliable for structural mapping.

The thickness of the Queen City formation on the east flank of the Van dome is not known because of faulting which is difficult to detect or estimate in the Queen City formation. The normal thickness should be between 275 and 300 feet.

WECHES FORMATION

The Weches formation, youngest in the Mount Selman group, forms a prominent range of hills far down on the south and east flanks of the Van uplift. It is composed of massive fairly pure clayey glauconite probably not in excess of 40 to 50 feet, though red staining from surface weathering gives the appearance of a greater thickness. The unweathered beds are greenish-blue in color and carry poorly preserved fossils; the exposed beds quickly turn deep reddish brown and the fossils rapidly deteriorate. In the Garden Valley area, on the east flank of the Van uplift, the Weches is fairly sandy and contains buff and red cross-bedded sandstones. Iron ore occurs irregularly throughout the formation. It is especially well developed at the top where it forms a cap, protecting the softer less ferruginous beds below. The main iron ore bed of east Texas is in the top part of the Weches formation.

SUBSURFACE GEOLOGY

DESCRIPTION OF FORMATIONS PENETRATED IN DRILLING

LOWER (COMANCHE) CRETACEOUS

The Lower Cretaceous at Van has been penetrated 3774 feet, and it is believed that there is at least an equal amount yet undrilled. What lies beneath the Comanche is problematical. The part of the Comanche that has been penetrated and studied reveals a distinct depositional history. The deepest penetration encountered the middle of a great sand body suggesting fairly shallow water but stable depositional conditions. Gradually the waters deepened as is indicated by the shales and limestones of the lower Glen Rose, continuing with fair depth throughout the anhydrite, limestone, and shale accumulation of middle Glen Rose time; later slightly deeper water conditions prevailed while the uniform shale and limestone of the upper Glen Rose were laid, and finally shallower water conditions existed during Paluxy time. The Fredericksburg and Washita indicate stable deposition in relatively deep water. This period of deposition was terminated by uplift and slight erosion. Though the unconformity between the Lower Cretaceous and the Upper Cretaceous is not great structurally, the environment changed sufficiently to inaugurate an entirely new depositional cycle, the

Woodbine formation, decidedly a contrast with the previous 1100 feet of sedimentation. There appear to be no marked angular or structural unconformities in the Lower Cretaceous thus far penetrated at Van, but there is rapid vertical change from one type of deposit to another, though in most places the change is gradational.

TRINITY GROUP

UNNAMED SANDSTONE AND SHALE

The oldest formation penetrated to date in drilling on the Van dome has not yet been named. Furthermore this particular part of the Trinity has not been separated at its outcrop from the remainder of the group which is referred to as Trinity, Antlers, or Travis Peak sands. Between 6485 and 7501 feet in Davis 6-T-1, on the northwest flank of the Van dome, slightly over 1000 feet of sandstone and shale were penetrated. From information obtained in drilling in Louisiana it is probable that at least an additional 1000 feet of similar material exists at Van.

At the top of this nonmarine section, which lies below the lower Glen Rose marine limestone and shale section, are red sandstones, red and gray shales, and lignitic sandstones. Directly below these beds the sandstones become coarser and grade into a conglomerate. There appears to be no marked lithologic break, but a gradation from limestone interbedded with sandstone to red shale, red sandstone, gray shale, lignitic sandstone and into coarser sandstone and conglomerate. The conglomerate grades downward into sandstone interbedded with gray and red shale. The entire thickness of 1000 feet of this deposit, penetrated in Davis 6-T-1, is remarkably similar. The sands are firm to hard, relatively fine, and vary from white and gray to red in color; the shales are red or gray or mottled in the two colors. In places the sands are lime cemented. About 80 per cent of the formation is sand; the balance is shale. With the exception of the conglomeratic bed between 6525 and 6532 feet which was cored, no other conglomeratic horizon was noted, though in drilling some thin beds could have been penetrated without being detected.

LOWER GLEN ROSE FORMATION

Gray, black, and tan-colored limestone, in places sandy; black and dark gray shale, locally carrying a little anhydrite; a relatively small amount of fine hard sandstone and a negligible amount of red shale constitute the 659 feet of lower Glen Rose penetrated in Davis 6-T-1. Between 6294 and 6329 feet sandy limestone, in places full of comminuted shell fragments, was cored and found to carry heavy black oil. Miliolids also contribute to porosity. Very little anhydrite was encountered, and apparently it is confined to two thin zones in the upper half of the formation. With the exception of a 30-foot bed of sandstone between 5965 and 5995 feet no important sandy zones were recognized in the lower Glen Rose.

GLEN ROSE ANHYDRITE FORMATION

The anhydrite section of middle Glen Rose age is 365 feet thick in Davis 6-T-1. This zone includes the main body of anhydrite, though there are a few stringers above and below. Consequently the thickness of the anhydrite section is a matter of opinion. The anhydrite is dense, gray, and hard. It grades into hard limestone and is interbedded with dark gray to black shale. Sand is almost entirely absent. At the base of the main anhydrite zone is a horizon of *Orbitolina texana* (Roemer). In Davis 6-T-1 the anhydrite section lies between 5461 and 5826 feet.

UPPER GLEN ROSE FORMATION

Hard gray limestone and hard dark gray to black shale in about equal amounts make up the upper Glen Rose. Thin streaks of hard sand occur in the upper 100 feet of this 515-foot section, but the balance of the deposit is barren of sand. In the basal 50 feet of the formation there is a little dense gray anhydrite which overlies the main anhydrite section of the middle Glen Rose. The upper Glen Rose lies between the base of the Paluxy at 4946 feet and the top of the Glen Rose anhydrite at 5461 feet in Davis 6-T-1.

PALUXY FORMATION

Firm gray and brown beds of fine sandstone varying from 1 inch to 20 feet in thickness, hard black and gray shale, gray sandy shale, and an occasional thin hard bed or lens of gray limestone make up the Paluxy formation which lies at the top of the Trinity group. In Davis 6-T-1 most of the Paluxy section, which was found between 4739 and 4946 feet, was cored. Though light saturation was observed in three separate horizons in the formation only salt water was obtained in a drill stem test. This is not surprising in view of the structural position of the test, nearly 1000 feet down the flank from the top of the dome. Though only 207 feet of Paluxy formation were identified in Davis 6-T-1, 272 feet were reported in Gardner Bros. et al. Leonard No. 1, 3 miles northwest of Davis 6-T-1 and farther down the northwest flank of the dome. It is doubtful if there is actually as much variation in the thickness of the formation as suggested by these records. The discrepancy is doubtless due for the most part to the selection of the base and the top of the formation.

FREDERICKSBURG AND WASHITA GROUPS

Lithologically the Fredericksburg and Washita constitute a remarkably uniform hard gray limestone deposit with a subordinate amount of black and dark gray shale, totaling 1100 feet. In Davis 6-T-1 there are 1012 feet present, but it is probable that this amount has been shortened from 100 to 200 feet by a fault which should cut the section but which has not actually been identified in the well itself. In Gardner Bros. et al. Leonard No. 1, 1100 feet of Fredericksburg and Washita are reported, and the character of the group is the same as found in Davis 6-T-1. Of the 1100 feet of Fredericksburg and Washita, 900 feet is limestone and 200 feet is shale. The largest bed of shale, comprising one-half of the total amount, is found in the basal 150 feet of the group. In the basal 300 feet of the deposit the limestone becomes lighter gray and carries many miliolids.

In the top 50 feet of the Comanche are copper-colored fossiliferous shales from 5 to 30 feet thick which grade upward into gray sandy shales usually 10 feet thick. These gray shales are the top member of the Comanche and grade upward without apparent break into the basal sands and shales of the Woodbine formation of the basal Upper Cretaceous. Since the same section of uppermost Comanche is found at Van in all wells penetrating the horizon, and as a similar section is found in other areas of the East Texas basin, it is believed that little, if any, material was eroded from the top of the Comanche at Van before the Woodbine was deposited.

UPPER CRETACEOUS

The usual sequence of Upper Cretaceous formations of east Texas is present at Van, though some of them are thin because of non-deposition. Faulting on the top of the Van dome thins the formations locally as all faults so far observed are normal tension breaks varying from less than a foot to approximately 1000 feet of displacement. This fracturing and displacing of beds on the top of the uplift has permitted porous formations overlying the Woodbine to become saturated with oil and gas from that horizon.

WOODBINE FORMATION

The Woodbine formation at Van is composed from top to base of bluish-gray and brownish-gray bentonitic or ashy sandstone, mottled red, white, blue, and greenish shales or clays, and fairly soft medium-coarse sand. Lignite particles occur throughout the deposit. All sands on the dome above the water level are saturated with oil or gas. On the highest part of the structure 650 feet of Woodbine have been measured, although because of faulting which cannot be detected readily unless it has considerable magnitude, there may be an additional 50 feet of the formation. In Davis 6-T-1, where it is fairly certain that the Woodbine is not faulted, 701 feet are present; in Gardner Bros. et al. Leonard No. 1, 3 miles northwest of and down the flank of the dome from Davis 6-T-1, there is an unfaulted section measuring 710 feet. A normal, full section of Woodbine in the Van region is 800 feet thick, so it appears that 100 to 150 feet are missing over the top of the Van dome, even if the formation is not faulted.

A more or less arbitrary division separates the Woodbine at Van into an upper or bentonitic and a lower or non-bentonitic section, but the line of demarcation can be drawn only approximately for the thickness of the bentonitic section varies widely in different parts of the field, and, furthermore, clean, non-bentonitic sands occur in the upper, bentonitic, section and bentonitic sands occur in the lower, non-bentonitic, or so-called brown-sand section. Red, gray, bluish, and purple mottled shales occur throughout the Woodbine, and there seems to be no regularity of their occurrence in the vertical section or distribution on the structure. The basal

150 feet of the so-called brown-sand section contains some lime-cemented fairly hard sandstones which have less than average porosity.

The bentonitic or ashy sands, predominant in the upper half of the Woodbine formation at Van, are greenish gray in general though in spots there is a pinkish tinge. They are usually soft and have almost no calcareous matter. Ash or bentonite is the cementing material, which binds the quartz grains together, and as this matrix is highly absorbent and porous, surprising porosity is developed in these upper sands, which on first inspection do not give the impression of being porous. Permeability, however, is low. The average bentonitic sand consists of 90 to 95 per cent fine angular to subangular quartz held together with 5 to 10 per cent ashy material. There are a few scattered grains of black chert.

The mottled shales or clays are really variously colored and tinted non-calcareous and colloidal ashes. The predominant colors are tints of red, blue, and green. There is a large amount of white and gray ash and various tints between red, blue, and green. These mottled shales give no evidence of oil on visual examination. The so-called brown-sands are friable and non-calcareous and are composed of white medium-coarse well assorted rounded or slightly angular quartz grains, held together by a small amount of ashy siliceous clay, often less than 5 per cent. Occasionally there are a few dark chert grains, and in some horizons enough large angular chert pebbles are present to make the sand conglomeratic. Much of the sandstone section is distinctly cross-bedded. The brown color of the sand above water level is due to oil stain. Considerable lignite occurs throughout the section.

A study of all Woodbine data at Van indicates that the formation averages 50 per cent sand and 50 per cent shale throughout the field.

The following sample descriptions and porosity determinations, together with geologic and Schlumberger logs (Pl. 26), give a fair conception of the Woodbine at Van.

Tunnell 300 No. 3 Well

No. of samples	Depth of core From	To	Location of tested specimens	Per cent group porosity	Core recovery
	Feet				
4	2505	2523	Middle 2 feet blue sandy shale	18.30	7 feet hard red and blue sandy shale

No. of samples	Depth of core From (Feet)	To (Feet)	Location of tested specimens	Per cent group porosity	Core recovery
3	2523	2533	Top to bottom	27.10	4 inches light brown sandstone; light petroleum odor 8 inches hard blue-gray sandstone; light petroleum odor
3	2533	2538	Top 1 foot hard blue sandstone	12.20	6 inches medium hard blue-gray sandstone; fair saturation
2	2533	2538	Bottom 1 foot soft blue sandstone	24.80	1½ feet hard blue-gray sandstone 1 foot medium hard blue-gray sandstone; fair saturation
4	2540	2550	Top to bottom 3 feet	29.10	6½ feet medium hard and soft blue-gray sandstone; light saturation
9	2550	2560	Top to bottom	30.00	8½ feet medium hard blue-gray sandstone; well saturated
3	2560	2578	Top 1 foot coarse sandstone with lignite	27.20	1½ feet medium hard gray sandstone; fair saturation
3	2560	2578	1 foot hard very fine sandstone	7.30	3½ feet medium hard gray sandstone; petroleum odor
4	2560	2578	2 feet gray sandy shale	21.20	3 feet red shale
2	2560	2578	6-inch layer of sandstone	17.60	6 feet gray shale with streaks of sand; 1 foot from bottom is a 6-inch layer of lightly saturated sandstone
2	2578	2596	Middle 1 foot gray sandstone	20.50	1 foot gray shale
9	2578	2596	Bottom 12 feet	25.90	1 foot gray sandstone, 12 feet hard light-brown sandstone, with a few thin streaks of shale; well saturated
7	2596	2614	Top 7 feet sandstone with shale and lignite	27.40	9½ feet hard gray sandstone with streaks of shale and lignite, fairly well saturated
3	2596	2614	Bottom 1 foot very hard sandstone	6.50	4 inches hard blue sandstone
4	2614	2617	Top to bottom	15.30	1⅔ feet very hard blue-gray sandstone
2	2617	2621	Top 1½ feet very hard sandstone with gravel	24.40	1½ feet very hard blue sandstone with some gravel

No. of samples	Depth of core From (Feet)	To (Feet)	Location of tested specimens	Per cent group porosity	Core recovery
3	2617	2621	1 foot blue shaly sandstone and 1½ feet red and blue sandstone	19.00	1 foot medium hard blue shaly sandstone showing a little oil 1½ feet hard red and blue sandstone
13	2621	2639	Top to bottom	25.20	15 feet medium hard blue sandstone; fair saturation
3	2639	2657	Top 3 feet blue sandy shale	20.00	3 feet blue sandy shale
4	2639	2657	Upper 5 feet blue sandstone	26.60	5 feet hard blue sandstone; lightly saturated 4½ feet gray shale
5	2639	2657	Bottom 5 feet blue sandstone	16.30	5 feet hard blue sandstone; petroleum odor
4	2657	2675	Top 2 feet blue-gray sandstone	15.80	2 feet blue-gray sandstone; lightly saturated 3 feet blue and red mottled shale
----	2675	2689	No determinations	--------	11 feet hard red and blue mottled shale
4	2689	2706	Middle 4 feet sandy bentonite	11.10	8½ feet hard red and blue sandy shale
4	2706	2724	Top 6½ feet red and blue sandy shale	11.20	6½ feet red and blue sandy shale 3½ feet red beds
7	2724	2740	2½ feet gray sandy shale Top of non-bentonitic or brown-sand section 2730 feet	12.60	6 inches red shale 2 feet gray sandy shale 2 feet red and blue shale 2½ feet gray sandy shale 3 inches soft brown sand; well saturated
14	2740	2758	Top to bottom	29.40	15 feet hard and medium hard sandstone; well saturated
6	2758	2776	Top to bottom	29.60	14 feet rich oil sand
2	2776	2794	Top 1 foot sand, shale, and pebbles	12.40	4 feet soft rich oil sand; bottom 8 inches hard
2	2776	2794	Middle 2⅓ feet brown sandstone	32.20	
2	2776	2794	Bottom 8 inches very hard sandstone	4.30	
4	2794½	2812	Top 1½ feet very hard gray sandstone	3.10	1½ feet gray hard sand

No. of samples	Depth of core From (Feet)	To	Location of tested specimens	Per cent group porosity	Core recovery
3	2794½	2812	2⅛ feet brown sandstone	29.30	2⅛ feet sand; well saturated 4 inches sand and shale; showing oil
3	2812	2826	Top 6 inches very hard gray sandstone	2.90	6 inches very hard gray sandstone
3	2812	2826	Bottom 4 feet brown sandstone	27.70	6 inches sand, shale and gravel, conglomerate 4 feet hard and soft brown sandstone; well saturated
5	2826	2843	Top 4½ feet brown sandstone	30.50	4½ feet hard brown sand; well saturated
3	2826	2843	1¾ feet gray shaly sandstone	13.10	1¾ feet red shale 1¾ feet gray shaly sand 7 feet red and blue mottled shale
3	2843	2852	Middle 2 feet shaly sandstone	10.30	3½ feet red and blue mottled shale 3½ feet hard red and blue mottled sandstone
5	2852	2857	Top to bottom	9.80	1 foot red and blue mottled sandstone 1 foot hard blue-gray sandstone 6 inches hard red and blue sandy shale 2 feet gray and blue sandstone
4	2857	2875	Top 7½ feet red and blue sandy shale (about 75% sandy shale)	11.70	7½ feet hard blue and red mottled sandy shale 6 inches hard brown sand; well saturated 6 inches light gray sandstone; petroleum odor
3	2875	2893	Top 1¼ feet brown sandstone	17.30	15 inches hard blue sandstone; well saturated
3	2875	2893	2¼ feet gray sandstone	11.40	4½ feet brown shale 2¼ feet hard gray sandstone
10	2893	2902	Top to bottom	13.40	1 foot hard reddish-gray sandstone 8 feet hard gray sandstone; in places lightly saturated

This well was completed at 2964 feet depth or 2450 feet below sea level in conformity with the practice of completing wells penetrating the brown-sand section about 50 feet above water level. Top of Woodbine formation in Tunnell 300 No. 3 is 2485 feet.

EAGLE FORD FORMATION

The Eagle Ford formation is composed of fossiliferous, well-stratified, laminated, dark gray and black, micaceous, pyritic shales with thin hard layers of sandstone. Some gray volcanic ash and waxy particles in the basal part of the shale give it a "salt and pepper" appearance. The Eagle Ford averages 425 feet in thickness around the periphery of the Van uplift, where it is not influenced by the structure, and 175 feet in thickness on top of the Van structure, where not thinned locally by faulting.

A muddy sand called the sub-Clarksville is developed just above the middle of the Eagle Ford in the territory surrounding Van. It attains off structure a thickness of about 40 feet and thins gradually up the flanks of the dome. On the top of the structure it is absent—it probably never was deposited. Where it is encountered sufficiently high on the structure, it carries oil and gas.

A study of the microfauna of the Eagle Ford in the Van field and surrounding areas has shown that the formation may be divided into three members, which are easily recognized. With the aid of this zoning it is not difficult to determine what part of the formation is missing from any particular well or area, due precaution being taken against a shortening of the section by faulting.

The map showing the distribution of the sub-Clarksville (Pl. 24) indicates a small area, including lease 500 and a small surrounding territory, in which the upper part of the Eagle Ford was eroded or never laid down; probably the latter, as there is no definite evidence of truncation or erosion. It is believed that this area was originally the top of the Van dome. Only the lower part of the Eagle Ford was deposited because the area was at shallower depth than the remainder of the structure during late Eagle Ford time. From this local area, on the north side of the main northeast-southwest fault which crosses the dome, the Eagle Ford thickens outward and down dip as does the sub-Clarksville sand within it. Also, several areas north of the main fault, such as at Crim 27 No. 1, Crim 27 No. 2, Brawner 10 No. 2, Crim 16 No. 1. and possibly Thompson 41 No. 1, have an abnormal thickness of Eagle Ford for the structural position of the wells with reference to the uplift as a whole. During Eagle Ford time these areas were probably lower than adjacent localities and received additional deposits. Local faulting during the uplift in Eagle Ford time is the most logical explanation for such restricted depressions.

A large area in which the sub-Clarksville sand is not present occurs southeast of the main fault, which crosses the dome in a northeast-southwest direction. Though observations are rendered less conclusive because of complicated faulting, it appears that the upper part of the Eagle Ford was not laid down. Both the Eagle Ford and its contained sub-Clarksville sand thicken gradually outward and down dip from this area of thin Eagle Ford and absence of sub-Clarksville sand. This suggests that a large area on the south side of the main fault, covering what is now the highest structural part of the dome, was relatively high in relation to the original center and top of the dome (area around lease 500) during Eagle Ford time. If this deduction is correct it means the main fault was moving and apparently was influencing sedimentation during Eagle Ford time. If this fault is at least as old as the beginning of Woodbine time, the 50 feet of thinning in the Woodbine formation on top of the present high area southeast of the fault may be explained. This age for some of the fault movement along the main line is further substantiated by the suggestion of at least 100-foot greater displacement in the Comanche than in the Woodbine. Furthermore, this would explain the unusually thick Eagle Ford just north of, and on the downthrown side of, the main fault.

AUSTIN FORMATION

The Austin formation is a relatively homogeneous deposit of soft gray and buff-colored chalk, calcareous clay, and nodular marl. A little sand and a fair number of pyritic nodules occur in places. The deposit contains a great abundance of mega- and microfossils. The chalk is deep brown or chocolate-colored due to oil and gas saturation in areas sufficiently high on structure along fault zones, where it is broken and fractured. In such places it is recognized only with difficulty in drilling. It is little harder than the shales above and below, and when its characteristic color is not present, keen observation is necessary to detect it.

Off structure at Van the Austin formation averages 315 feet; normal, unfaulted sections on top of the dome measure 200 feet. Since the Austin has not been zoned, it is not known if a particular part is missing or if the entire section is thinned because of non-deposition.

LOWER TAYLOR FORMATIONS

The lower Taylor includes those gray shales, gray and buff marls, and chalks which lie below the Pecan Gap and above the Austin. Normal, unfaulted sections on the top of the Van dome have 800 feet of lower Taylor which increases off structure to 925 feet. Only a small amount of sand is found, and it is distributed without forming sand zones. Fossils are common. There appears to be no depositional or structural break at the base or at the top of the lower Taylor.

PECAN GAP FORMATION

The Pecan Gap chalk at Van is lithologically not greatly different from the Austin chalk, with the probable exception that it is slightly harder. Its thickness is 150 feet where it is normal and not affected by the uplift and 130 feet on the top of Van dome where faults do not cut it. There was evidently little thinning over the Van structure during Pecan Gap time.

This chalk horizon is the first good lithologic marker encountered below the surface in the Van region and is an exceptionally reliable horizon for subsurface mapping especially in areas of wildcat wells where mediocre records are kept.

The Pecan Gap chalk is highly saturated with oil and gas along faulted and fractured zones near the top of the Van structure. Under such conditions it loses its characteristic color and becomes dark brown. Like the Austin, it is then difficult to recognize. As in the Austin, saturation of the Pecan Gap with oil and gas along faults and fractures suggests upward migration from the Woodbine.

UPPER TAYLOR FORMATION

Conditions governing sedimentation were stable in the Van region during upper Taylor time. The upper Taylor retains a constant thickness of 400 feet across the Van uplift. Uniform fossiliferous gray shale and gray sandy shale carrying a few thin fairly hard chalky limestone beds constitute the deposit. Locally the shales contain pyrite and glauconite. They show no marked change upward into the Navarro, and though a decided lithologic change occurs at the top of the Pecan Gap chalk, no discordance is evident at that level.

NAVARRO FORMATION

The Navarro formation at Van is composed of fossiliferous gray sandy, and in places calcareous, shale containing pyrite, glauconite, and thin laminae of sandstone. In the lower part of the upper half of the Navarro a fairly constant muddy, shaly sand is developed; it is the Nacatoch and is between 15 and 20 feet thick. In some places it is cleaner than in others. Where it is shaly it is difficult to differentiate from the Navarro shales above and below, and such conditions doubtless account for its apparent variation in thickness.

The Navarro at Van is 300 feet thick off structure and averages 250 feet over the top of the dome. The oil and gas with which it is locally saturated evidently come from below, doubtless up along fractures and faults because along such features the best concentration is found. Fossils are common, and the formation is readily recognized in microscopic work.

The Navarro grades without visible break into the upper Taylor beneath it. Good lithologic and structural evidence of an unconformity occurs at the top of the Navarro, at its contact with the Midway. The Navarro is more highly folded and faulted than is the Midway. Furthermore, the basal greensand of the Midway, with its pebbles and re-worked Navarro material and fossils, is definite proof of an unconformity of magnitude, at least on the Van structure.

TERTIARY

EOCENE

Only the Midway and the Wilcox groups of the Eocene are found on top of the Van dome—the Midway thinned to about two-thirds of its normal thickness for the region and only 300 feet of the basal part of the Wilcox left by non-deposition and erosion.

Outward from the apex of the structure the Midway and Wilcox thicken. Three miles down the northeast, east, and south flanks the Wilcox passes under the unconformably overlying Reklaw—the Carrizo apparently is concealed locally by the overlap. White deep surface sands suspiciously like Carrizo occur on the northeast flank of Van dome overlying the Wilcox, and it is possible that a few feet of Carrizo have been uncovered by erosion of the overlapping Reklaw.

Overlying the Reklaw and dipping away from the dome on the east and southeast flanks is the Queen City formation which in turn is overlapped by the Weches greensand that forms prominent ridges which lie on the horizon east and southeast of Van.

MIDWAY FORMATION

Only two of the three members into which the Midway formation is divided on the surface in east Texas have been recognized in subsurface studies at Van. Shales and clays seem to extend without change downward through the section to the basal sandy glauconitic member which is the Littig greensand. Most of the Midway group is made up of gray fossiliferous silty shale locally having a little bentonite, calcite, mica, finely disseminated lignite, and pyrite. The basal 75 feet are more sandy and glauconitic than the upper 575 feet and are thought to include the Littig member. The base of the Midway carries considerable re-worked Navarro material, including fossils. The Midway of the Van region is about 900 feet thick off structure, but unfaulted sections measure 650 feet on top of the dome. Apparently the Midway thins considerably over the Van dome, but there seems to have been no development of the reef limestone which is characteristic of the section at Pisgah and Tehuacana ridges in Limestone and Navarro counties.

Sand lentils in the Midway, and especially the basal silty sand of the Littig member, carry oil and gas along fault zones at and near the top of the Van structure. This oil, like that found in other formations above the Woodbine, is considered to have its source in the Woodbine.

There is a decided lithologic change from tough clay and shale of the upper part of the Midway into the overlying lignitic sands and sandy shales of the Wilcox, but it is difficult to determine on the dome if there is a stratigraphic break. Characteristic Midway fossils are found together with an abundance of re-worked fossils from the underlying Navarro.

WILCOX FORMATION

All but the basal 300 feet of the Wilcox are gone from the top of the Van dome. Outward from the apex the remaining 800 feet of the group (as developed in the region) are found after the beds dip under the unconformably overlapping Reklaw, which rests on truncated Wilcox beds.

The basal part of the Wilcox as found on the top of the Van dome is composed of fine loosely-cemented gray and brown micaceous ferruginous lignitic sandstone, gray and buff sandy pyritic lignitic shales carrying irregular beds of poor quality lignite, and shaly calcitic pyritic sandstones containing silicified wood and limonite pebbles. Locally the sand is so powdery that after rains quicksand is formed.

Saturation of oil and gas has been found in drilling along fractured and faulted zones. Doubtless gas escapes into the air and would be noticed if the top of the dome were covered with water because saturation has been encountered in one place at only 160 feet below the surface, and active gas seepages have been observed in small areas inundated after heaving rains.

In east Texas in general, the Wilcox strata carry abundant and good water, which is fairly high in iron content, but from the apex of the Van dome to 3 miles down the flanks, water is scarce and of poor quality.

GEOGRAPHIC, STRATIGRAPHIC, AND STRUCTURAL POSITION OF THE VAN DOME

The apex of the Van dome is located just north of the town of Van in the southeastern part of Van Zandt County. With respect to the East Texas embayment, the top of the dome is 15 miles west of the synclinal axis and about 100 miles eastward and down dip from the outcrop of the Woodbine formation.

Beds of lower Wilcox age are the oldest formation exposed on top of the dome. The magnitude of the uplift increases with depth, so that the Woodbine is approximately 2700 feet above its normal position.

STRUCTURE

SURFACE STRUCTURE MAP OF THE VAN DOME

The accompanying structural map (Pl. 10), which is a copy of the original surface map of the Van dome, shows the Reklaw outcropping northeast, east, southeast, south, and southwest of Van, but it does not show the continuation of the greensand west of Ben Wheeler. Work was suspended before the Reklaw was followed along the outcrop to a point north of Martin's Mills where it swings sharply to the southwest on its normal strike.

The dip of the narrow belt of Reklaw rimming the dome approximately one-third of the way down its east and south flanks averages about 100 feet per mile. This is considerably more than the normal dip of the region and indicates local uplift to the west with consequent steepening of the east flank of the structure. The character of the Wilcox does not permit definite observations of structure; over the Van dome fresh exposures in the Wilcox are few and cannot be correlated.

Some geologists report Carrizo sands in the long syncline that terminates the Van uplift on the west and extends from Martin's Mills to Grand Saline; others consider these sands to be Wilcox. Carrizo may well be preserved in this structurally low area. However, on the south and east flanks of the Van dome, the Reklaw laps across and conceals the Carrizo and rests directly on the Wilcox. On the northeast flank of the Van dome there are some deep white sands on the surface that may be Carrizo exposed by erosion of overlapping Reklaw.

Though the surface mapping of the Van uplift is not as satisfactory as could be desired, it does show a structural disturbance of great magnitude.

CORE DRILLING CONFIRMATION OF THE VAN DOME

A surface blanket of sand and soil which conceals the outcrop of the Wilcox group over the top of the Van uplift, together with impossibility of mapping with certainty any bed in the Wilcox, and the inability of refraction seismograph surveys to locate the apex of the structure made it necessary to drill core holes in an attempt to find a proper location for testing the Woodbine formation.

Recommendation was made on December 4, 1928, to drill two lines of core holes crossing each other near the town of Van, which appeared to be the highest point on the structure, judging from surface mapping and refraction seismograph work. Between January 18 and July 27, 1929, eight core holes were drilled. The results of this work are shown by a structural contour map drawn on the top of the Navarro (Pl. 11).

The first core test was located on the Mrs. M. P. Neils tract in the Jas. Rose Survey because this farm was considered to be on or near the top of the structure. Drilling began January 18, 1929, with a light rotary rig, which was used throughout the exploration. The test was drilled to 1125 feet and was abandoned on February 11, 1929, in the Navarro formation. As the Wilcox and Midway were found to be abnormally thin in this test, the next location was made on the J. T. Williams tract in the Antonio Rodriquez Survey, 3 miles east of the Neils test. At this locality the Reklaw greensand is at the surface, and a check could more nearly be made of the total thickness of the Wilcox formation, thus determining whether the abnormally thin section encountered in the Neils core test was due to erosion on top of structure or to a normally thin Wilcox in the Van region. The Williams test was started February 19, 1929, and was abandoned in the Navarro at 1801 feet. It proved conclusively the Midway and Wilcox to be exceptionally thin on top of the Van dome, and it revealed also an abnormally steep east dip, thus confirming structure. Later data have shown that even at this locality, halfway down the flank of the structure, the total Wilcox section is not present, nearly 200 feet having been eroded before the Reklaw was laid unconformably on the Wilcox.

The third test was located on the N. A. Henderson tract in the Wm. H. Hazelwood Survey, 3 miles west of the Neils core test, to determine whether west or reverse dip existed. Drilling began on March 26, 1929, and the test was abandoned on April 8, 1929, in the Navarro formation at 1536 feet.

To confirm the rate of west dip the fourth core test was located on the J. M. Martin tract in the J. Stephenson Survey. It was started April 16, 1929, and was abandoned on April 21, 1929, in the Midway formation at 615 feet.

Structural uplift at Van was confirmed by the east-west line of core holes. A north-south line was then begun to determine if closure existed. Since the surface outcrop of the Reklaw on the south flank of the Van structure indicated a steep south dip, it was felt that south dip would doubtless be present and even be accentuated in the subsurface. But as there was practically no control on the north limb, it was decided to drill a core hole on the W. S. Brannon tract in the J. Goodman Survey, 3 miles north of the Neils core test. The Brannon core test was started on April 27, 1929, and was completed on May 15, 1929, at 1752 feet in the Taylor formation. Saturated sands in the Midway, Navarro, and Taylor gave good showings of oil and gas between 574 and 1230 feet. This was the first actual evidence of oil and gas on the Van structure.

Confirmation of the observed south dip of the Reklaw was desired, and the W. C. Gilbert test was located in the J. D. Coffman Survey, 3 miles south of the Neils core test. Drilling was started May 23, 1929, and on May 31, 1929, the test was abandoned in the Midway at 1030 feet. This information proved conclusively the presence of a large domed anticline at least 6 miles in diameter with its apex just north of the town of Van; it further showed the presence of oil and gas.

A core test was located on the L. A. Smith tract in the John Walling Survey because surface outcrops in road cuts and drainage features had suggested faulting with northeast-southwest trend and high topography had indicated the possibility of relatively high structure northeast of the town of Van. Drilling began June 10, 1929, and the test was abandoned June 27, 1929, in the Pecan Gap chalk at 1593 feet. Several showings of oil and gas were encountered between 903 and 1593 feet; the best saturation was found in the Nacatoch sand which is fairly well developed. In this test the upper Taylor is missing, and the Navarro rests on the Pecan Gap, indicating about 400 feet of fault displacement with the downthrow side to the northwest. Later drilling proved the Smith core test to be cut by the main northeast-southwest fault of the dome. As indicated by topography, the Smith core test is relatively high structurally.

Finally a core test location was made on the V. T. Davis tract in the M. Gross Survey. Drilling began June 29, 1929, and the test was abandoned July 26, 1929, in the Pecan Gap at 1725 feet. This location was drilled to check the strike and determine the amount of throw of a surface fault observed in a road cut near the location. Drilling proved the fault to be upthrown on the north side and to have approximately 100 feet displacement. Showings of oil were encountered in the sandy phase of the basal Midway, including the Littig member, and in the Navarro, especially in the Nacatoch sand which though muddy has fair development. It was estimated at the time of drilling that the Brannon, Smith, and Davis core tests could have been completed each for about 10 barrels of oil per day from the Nacatoch. Later production tests of wells drilled in the vicinity of these core tests substantiate the estimate.

The top of the Navarro was used as a contour horizon for subsurface structural mapping (Pl. 11) because of its reliability and definiteness. Location for a Woodbine test was made on the W. T. Jarman tract in the extreme southeast corner of the Nacogdoches School Land Survey following the subsurface structural mapping. This location was selected because it is on the apex of the structure, because it should cross at shallow depth the southwest-northeast trending fault revealed by the Smith core test, and should reach the Woodbine formation on the upthrown side of the fault.

STRUCTURE OF THE VAN OIL FIELD INDICATED BY DRILLING

STRUCTURE ON TOP OF THE MIDWAY FORMATION

The top of the Midway formation is the least satisfactory horizon of any used in detailed structural mapping of the Van field. As the uppermost Midway beds are poorly fossiliferous and the basal part of the Wilcox group contains re-worked Midway fossils, it is often difficult to separate the two. A few datum figures have been discarded because they are obviously in error, but the percentage is negligible.

The area covered by the structural map on top of the Midway (Pl. 12) is practically coincident with the outline of the productive area of the Woodbine. It is unfortunate that control points are not available over the entire area involved in the Van structure so that a comprehensive picture might be had of the whole uplift, but so few points of control are to be had outside the Van field that preparation of a map of the entire disturbance in the Midway is not warranted.

In examining the Midway map it should be remembered that the Van field covers only a small area on top of the Van uplift—7 square miles in comparison with 500 square miles—and that a more complete picture might give a different structural interpretation to some of the mooted localities.

In general the structure on the top of the Midway bears a remarkable similarity to the structure of the underlying formations, if one keeps in mind the increase in degree of folding and faulting with depth and the several disconformities and unconformities that are present.

A major fault or fault zone downthrown to the northwest crosses the field in a northeast-southwest direction and has 250 feet throw at the southwest end of the field. This increases to a throw of between 300 and 400 feet in the center of the field and continues with approximately the same size to the northeast end of the field. Outside of the field it rapidly diminishes in throw. Along the southeast or upthrown side of the fault are local closures of closed "highs." Through the center of the field, and a few hundred feet north of the main down-to-the-northwest fault, there is a compensating or down-to-the-southeast fault, which has between 100 and 200 feet of throw at its center, and diminishes toward each end as it approaches and joins the main fault. These faults form a long narrow graben extending from the center halfway to the northeast and southwest edges of the field. Radiating outward and southward from the main fault are secondary faults and synclines that conceal or are equivalent to faults. On the north side of the main fault, and on the north side of the graben where present, the Midway in general rises gently, forming a long broad ridge parallel and equal in length to the graben. Along the north edge of this ridge are two notable closures, which can be readily recognized in all structural maps on older beds, down to and including the Woodbine. Control is lacking below the Woodbine. One of these highs is at lease 500 and is believed to represent the original apex of the dome; the other one lies 2500 feet southwest of the first.

An irregularity is found at the southwestern edge of the field where there is a closed structural depression of 400 feet depth. Complicated, intense local faulting may be responsible for the existence of this erratic low, but the faults could not be established with the available control. Though not satisfactory, this interpretation given to the Midway structure must suffice until more information is available.

STRUCTURE ON TOP OF THE NAVARRO FORMATION

The structural picture, given by contouring the top of the Navarro (Pl. 13), is intermediate between that obtained by contouring the top of the Midway and the top of the Pecan Gap.

The main northeast-southwest trending fault, upthrown on the southeast side, cuts across the field. It has moved to the northwest as it has progressed deeper in the geologic section. This fault has a throw of about 350 feet at the southwest edge of the field and retains approximately the same throw across the field, but outside the limit of the field it decreases rapidly in throw. The narrow graben in the center of the field, so marked on the top of the Midway, is present on the top of the Navarro, though modified considerably. The fault which forms the north limit of the graben and is upthrown to the northwest has about 150 feet throw near its center and diminishes in size toward each end as it approaches and joins the main fault. A curious complication is the sharp closed structure in the middle of the graben and the structural ridge which connects it with a similar high on the north side of the graben. This feature is indicated on the Midway map also. Extending southward and outward from the main fault are radial faults of lesser displacement than the main fault and synclines which may prove to be faults when further control is available. A comparison of the Midway map with the Navarro map shows fewer synclines and more faults southeast of the main fault in the older formation. This is due to greater displacement in the Navarro than in the Midway and to the fact that the top of the Navarro can be more accurately determined than the top of the Midway. The general increase in throw of these radial faults outward and southward from the main fault is interesting; some have a displacement of 100 to 150 feet at the south edge of the field but die out completely before they reach the main fault a mile distant. Other small faults begin and die out between the main fault and the south limit of the field.

The faulting seems to be irregular southeast of the main fault. Some faults are upthrown to the east; others are upthrown to the west. Grabens, horsts, and inclined blocks are formed as stresses from below were taken up. North of the main fault and its accompanying subsidiary graben a clearer picture is obtained by contouring the top of the Navarro than is suggested by mapping the top of the Midway.

Conforming with the Midway map, a broad anticlinal ridge occurs in the Navarro paralleling the main fault, approximately the length of the graben. Northwest of and parallel to this ridge is a graben approximately 2000 feet wide, narrowing at both ends as the limits of the field are approached. This graben is formed by two faults of approximately equal throw, 50 to 100 feet. Within the graben two small closed structural "highs" occupy about the same position and relation to each other as the highs mapped in the Midway. The northeasterly high is thought to be the original top of the dome, and the southwesterly one is about 2500 feet southwest of the first. Northwest of and parallel to the graben is a fault that is upthrown on the northwest and has 150 feet throw at its southwestern end and diminishes to 50 feet at its northeastern end where control is lacking. The beds dip away gradually from the top of the dome to the west, northwest, and northeast of this fault.

STRUCTURE ON TOP OF THE PECAN GAP FORMATION

A map of the top of the Taylor is not presented in this study because it is merely a repetition of the structure shown by contouring the top of the Pecan Gap for the upper Taylor is not thinned over the Van dome. Preference was given to the Pecan Gap because it can be recognized both lithologically and faunally in the field and therefore is conducive to less error than the top of the Taylor. Furthermore, in wildcat wells the Pecan Gap is usually logged with fair accuracy, and sufficient control points have been obtained to enable the preparation of a structural map of the entire area involved in the Van uplift.

The structural map of the Van field contoured on top of the Pecan Gap chalk (Pl. 14) is more clear-cut and definite than the Navarro or Midway maps.

Across the field from southwest to northeast extends the main fault. The fault has shifted to the northwest as it progresses deeper into the geologic column. It has 350 feet throw at the southwest edge of the field and holds to this throw across the field. The radial faults extending southward from the main fault are definite and well established. They can be identified with ease in successively older beds, and their migration in the direction of their dip as they are mapped on successively older beds is enlightening.

Local closures occur along the trace of the main fault in the Pecan Gap on the upthrown side of the fault. These "highs" close directly against the fault in all places on the Pecan Gap map, whereas on the Navarro map several close on themselves and have a dip, or drag, into the fault. Most of the high areas on the Midway map close on themselves and have a decided drag or dip into the fault. This may be explained by the relative competency of the beds. However, in contouring structure on formations below the Pecan Gap, the high areas close against the faults as in the Pecan Gap regardless of the character of the formation. Possibly the amount or weight of the overload while the faulting and uplift took place enters into the result.

Northwest of the main fault and paralleling it through a considerable part of the field is the same broad flat anticlinal ridge which has been recognized in upper formations. However, the narrow graben along the main fault is not evident, though the steep dip into the main fault from the northwest may be a remnant of the graben.

Northwest of the anticlinal ridge and parallel to it is the same structural graben observed in the Navarro. The bounding faults have 100 to 125 feet throw, an increase over their throw in the Navarro. They have also migrated toward each other, narrowing the width of the graben to not more than 1500 feet. The two locally closed structurally high areas persist in their same geographic positions. The fault northwest of the graben also has migrated southeastward, and to the west, northwest, and northeast of this fault begins the regular dip on the flanks of the dome.

REGIONAL STRUCTURE OF THE VAN UPLIFT CONTOURED ON TOP OF THE PECAN GAP FORMATION

Though points of structural control on the Pecan Gap chalk outside of the Van field are not as adequate as could be desired, there are enough of them to give a fair picture of the entire uplift (Pl. 15).

The main fault which crosses the field, which is situated on top of the dome, apparently extends with decrease in throw for a considerable distance to the southwest, at least as far as the syncline which limits the uplift on the west. To the northeast this main fault has not been found far outside the field, possibly because of lack of control in the critical belt. The secondary fault which is upthrown on the northwest and lies northwest of the original apex of the dome continues for a distance to the northeast but with decreasing displacement in that direction. The radial faults die out a short distance down the flanks of the uplift. Their outward limits are not accurately controlled because of lack of data.

Regionally the Van uplift as mapped on the Pecan Gap chalk is a great, slightly elongate domed anticline surrounded by structurally low synclines. In the syncline at the northwest corner of the Van uplift is Grand Saline salt dome; in a profound structural low on the axis of the East Texas embayment at the northeast corner of the Van uplift is Haynesville salt dome; at the southeast corner of the Van uplift, and close to the axis of the East Texas embayment is Mt. Sylvan salt dome; at Martin's Mills is a low synclinal area at the southwest corner of the Van uplift in which a salt dome may exist.

From the apex of the Van dome to the syncline which bounds it on the southwest 10 miles away, there is a reverse or southwest dip of 1500 feet; the northwest dip is 1300 feet in 5 miles into a saddle which lies between a broad southeast plunging nose and the northwest flank of the Van closure. There are 1300 feet of effective closure on the Van dome on the top of the Pecan Gap chalk. Northward the dip is about 1500 feet in 10 miles. South dip is about 1700 feet in 10 miles; and eastward there is dip for 15 miles to the axis of the East Texas embayment which is 2300 feet structurally lower than the top of the Van dome.

STRUCTURE ON TOP OF THE AUSTIN FORMATION

A contour map of the Van field on the top of the Austin (Pl. 16) differs from a contour map on the top of the Pecan Gap only in normal changes attendant to growth. The position of the main northeast-southwest trending fault, which is upthrown to the southeast, has migrated considerably to the northwest as it has been migrating or dipping from the surface. In this direction its face also is becoming wider as each successively older formation is encountered because of increased displacement of beds, or throw. The minor radial faults on the southeast side of this main fault likewise have shifted down the dip of the fault planes, and some have noticeably more throw and wider fault faces than in the younger formations.

The main fault has a displacement of 500 feet at the southwest limit of the field and only about 300 feet displacement in the center of the field where a structurally high ridge connects the upthrow area southeast of the main fault with the original top of the dome on the northwest side of the main fault. This ridge is not so prominent on structural maps of younger formations. Farther to the northeast the throw increases to 700 feet and then rapidly diminishes to 250 feet at the northeast edge of the field.

Northwest of the main fault, the downthrown beds rise to the structural ridge previously described. However, on the top of the Austin this ridge has shifted a little to the northwest.

The two parallel faults, which in the Navarro and Pecan Gap form a graben across the original top of the dome and which in successively older formations are dipping or migrating toward each other, thus narrowing the graben between them, have crossed each other just above the Austin chalk with the result that there is a narrow horst where the graben is in higher beds, and the locally closed structural highs in the graben are now local closures on the horst that continues to widen as older formations are reached.

The small fault which is upthrown to the northwest and lies just northwest of the original top of the dome continues to dip southeastward. On the west, northwest, and northeast of this fault the Austin slopes normally away from the top of the structure, retaining the characteristic northwest shoulder which is also evident in the Navarro and Pecan Gap.

REGIONAL STRUCTURE OF THE VAN UPLIFT CONTOURED ON TOP OF THE AUSTIN FORMATION

In general the form of the Van dome on the top of the Austin formation (Pl. 17) is the same as on the top of the Pecan Gap chalk. The main fault which extends for a distance down the flanks of the uplift shifts in position as is to be expected. It is interesting to note the minor importance in the Austin of the fault which is upthrown to the northwest and lies northwest of the original top of the dome.

The synclinal areas which bound the Van uplift on all sides, and the shallow salt domes in them, retain the positions indicated by the regional mapping of the Pecan Gap chalk; however, the flanks of the uplift are considerably steeper on the Austin than on the Pecan Gap chalk. Reverse dip on the southwest flank is 2000 feet on the Austin, as compared with 1500 feet on the Pecan Gap; the northwest dip of the top of the Austin chalk is 1700 feet in 5 miles as compared with 1300 feet on the top of the Pecan Gap chalk; the effective closure on the top of the Austin chalk is 1700 feet. The same broad southeastward plunging nose coming toward Van from the northwest is present in the Austin as in the Pecan Gap chalk. Also, the northeast-southwest elongation of the Van dome is the same in the Austin as in the Pecan Gap chalk. This elongation of the dome is coincident with the strike of major faulting on the dome and with the general grain or regional strike on the west flank of the East Texas embayment. The northeast-southwest elongation, the southeastwardly plunging regional nose trending toward the northwest shoulder of the Van dome, and a structural bulge on the southeast flank of the dome indicate the quaquaversal nature of the uplift.

South dip on the Van dome is about 2000 feet in 10 miles, and in a like distance on the north flank the dip is also about 2000 feet. Eastward there is a dip for 15 miles to the axis of the East Texas embayment, giving a structural drop of 3000 feet.

STRUCTURE ON TOP OF THE EAGLE FORD FORMATION

The structural contour map on the top of the Eagle Ford (Pl. 18) more closely resembles contouring on top of the Woodbine than it does contouring on top of the Austin. There are several reasons for this. Minor faults which are difficult to detect in the thick chalk section of the Austin are readily recognizable in the thinner Eagle Ford; furthermore, some minor faults which are easily mapped in the Woodbine and in the Eagle Ford apparently do not carry upward into the Austin. The top of the Austin also is not as definite a horizon as either the top of the Eagle Ford or the top of the Woodbine. Thinning of the Austin and the Eagle Ford over the Van dome gives the top of the Eagle Ford a steeper slope than the top of the Austin.

The main northeast-southwest trending fault which crosses the field, and is upthrown on the southeast side, has a displacement of 450 feet at the southwest limit of the field. Slightly west of the center of the field, the north plunging ridge or nose which connects the upthrown southeast side of the main fault with the original top of the dome northwest of this fault, is more definitely shown than on the top of the Austin. The displacement of the main fault where crossed by this structural ridge or nose is only 300 feet. Northeastward from this ridge crossing of the fault, the throw of the main fault increases to 650 feet in a distance of 2 miles, and from that localitv the throw decreases to the northeast as the edge of the field and the flank of the dome are approached.

Northwest from the main fault the Eagle Ford rises for half a mile, forming a structural ridge which closes against the southeasterly fault and side of the horst and connects with the northerly plunging structural nose that crosses the main fault zone. The horst which crosses the original top of the dome has widened considerably more than indicated on the Austin map due to the outward dip of the two faults forming it. In the center of the horst, at lease 500, the same high structurally closed area persists at the locality where the top of the original dome is considered to be. Just northeast of this high, and also on the horst, a second closure has developed.

The easterly swing of the northeastern ends of the faults, which form the graben on the Navarro and Pecan Gap maps and the horst on the Austin and Eagle Ford maps, and their probable junction with, or merging into, the main northeast-southwest fault are interesting. Indications of this swing can be detected in the Navarro contouring and can be more clearly followed in the mapping of successively older formations.

The up-to-the-northwest fault which is well defined on maps of younger formations, cannot be traced in the Eagle Ford and Woodbine except for a short distance on the southwest side of the field because of lack of data for control in the critical area. Most of the wells used for mapping this fault in the younger formations were abandoned in or above the Austin.

The northwest shoulder of the Van dome, which connects by a saddle with the broad regional nose that plunges southeastward toward the Van uplift and which is shown on regional maps (Pls. 15, 17, and 20), is definitely present in the Eagle Ford.

STRUCTURE ON TOP OF THE WOODBINE FORMATION

The most accurately identified horizon in the Van field is the top of the Woodbine formation. No datum point on the Woodbine is considered to be more than 2 feet in error. The structural map on this horizon (Pl. 19) has been contoured, using a 50-foot contour interval, and showing the fault faces exposed between the top of the Woodbine formation on the upthrown and the same horizon on the downthrown side of the faults. This is the same scale, contour interval, and method used in contouring the structure of the younger formations mapped. Consequently by arranging the maps in consecutive geologic order the development of the top of the Van dome may be observed. This series of detailed structural maps of the field, used in conjunction with the regional structural maps, presents a fairly comprehensive history of the growth and structural development of the whole Van dome.

On the top of the Woodbine at the southwest edge of the Van field the displacement in the main up-to-the-southeast fault is 350 feet. There seems to be no explanation for the greater fault displacement in the Eagle Ford at this location. On the structural nose, crossing the main fault in the west-central part of the field, the fault displacement is likewise 350 feet, but toward the northeast the displacement of the main fault increases to 1000 feet and then decreases rapidly to 450 feet at the northeastern edge of the field.

Minor faults which radiate outward and southward from the main fault present an intricate pattern which doubtless will be further complicated when several synclines, now suspected of concealing faults, are better controlled by data from drilling.

Along a considerable portion of the main fault face, northeastward from the structural nose which crosses the main fault, Comanche rocks are present. A maximum of 300 feet of vertical

Comanche section appears in the face of the fault because the fault displacement is 300 feet in excess of the thickness of the Woodbine formation. From its maximum thickness of 300 feet the Comanche wedges out in the fault face to the northeast and southwest as the throw of the fault diminishes. The photograph of a model of the Woodbine formation in the Van field above an elevation of 2500 feet below sea level (Pl. 1) shows the Comanche present in the fault face.

Northwest from the main fault the Woodbine rises to the northwest, forming a structural closure and ridge against the horst and connecting on the southwest with the structural nose which crosses from the upthrown to the downthrown side of the main fault. The horst itself has widened over the amount shown on the Eagle Ford map, and the structural closure within the limits of the horst, at lease 500, has shifted slightly to the northeast and has merged into the structural closure noted on the Eagle Ford map at this locality.

It is possible to trace the up-to-the-northwest fault only a short distance from its southwestern end, due to the same lack of control mentioned in discussing the Eagle Ford map. The flanks of the dome dip in a normal fashion northwest, north, and northeast from the horst. Also the northeast swing of at least one of the two faults that form the horst across the original top of the structure is indicated, but adequate control is lacking.

REGIONAL STRUCTURE OF THE VAN UPLIFT CONTOURED ON TOP OF THE WOODBINE FORMATION

Regionally the Van uplift is a great quaquaversal anticline elongated in a northeast-southwest direction and bisected nearly along the apex by a main fault zone which has its maximum displacement near the top of the dome. Radial faults are developed on the southeast or upthrown side of the main northeast-southwest trending fault, but they die out a short distance down the flank of the dome. Their presence and number on the upthrown side of the major fault and their absence on the downthrown side of the major fault and on the northwest flank of the original dome suggest that the southeast or upthrown side of the main fault moved upward to its present position, rather than the downthrown side moved down.

Control foı the position and extent of the two faults which reach beyond the limits of the field is inadequate. Their mapping is therefore subject to change as information is obtained.

The form and outline of the Van dome, contoured on top of the Woodbine, presents practically no change from that indicated by contouring the top of the Pecan Gap and the top of the Austin. The synclines, which surround the Van uplift, and the shallow salt domes, Grand Saline, Haynesville, and Mt. Sylvan, which are located within them, occupy their regular positions. However, the top of the Woodbine has greater structural uplift or relief than the younger formations.

The southwest dip totals 2600 feet in 10 miles; northwest dip totals 2500 feet in 8 miles. The structural saddle limiting the Woodbine uplift on the northwest has migrated considerably farther to the northwest from its position in the Austin and Pecan Gap. North dip for 10 miles into deep syncline, which reaches westward from Haynesville salt dome and the axis of the East Texas embayment to Grand Saline, is 2800 feet. South dip for 10 miles, to the deep syncline which reaches from the axis of the East Texas basin through Mt. Sylvan salt dome to Martin's Mills, is over 3000 feet. East dip for 15 miles, to the axis of the East Texas embayment is 3500 feet. The effective closure of the Van uplift on top of the Woodbine is 2500 feet. The drainage area limited by present structural features exceeds the area of effective closure and totals approximately 500 square miles.

STRUCTURE ON TOP OF THE COMANCHE

Comanche rocks have been reached in wells drilled on the highest structural part of the Van field adjacent to the fault face on the upthrown side of the main fault which crosses the Van dome from southwest to northeast. They lie beneath the Woodbine and dip to the southeast away from the main fault at the same or a slightly greater rate than the Woodbine (Pl. 22). Wells drilled adjacent to the main fault, and on its south or upthrown side, are completed at 2450 feet below sea level, thus being bottomed about 50 feet above the original water level in the Woodbine. Consequently only a relatively few wells compared with the number drilled have reached the Comanche in this area. Therefore, the control is inadequate to permit accurate location, except adjacent to the main fault, of the radial faults which extend southward and outward from the upthrown side of the main fault.

In general structural contours on the Comanche close directly against the main fault without indication of dip or drag into the fault.

On the northwest side of the main fault Comanche rocks have been drilled into in three wells, which are located at the edge of the Woodbine productive area. They encountered the Comanche from 600 to 1000 feet, depending on their location, structurally lower than it occurs on the upthrown side of the main fault. Three miles northwest of the northwest limit of Woodbine production, and farther down the flank of the dome, Gardner Bros. et al. Leonard No. 1 reached the top of the Comanche 1400 feet below its structural level on the upthrown side of the main fault in the Van field.

No attempt has been made to contour the top of the Comanche on the downthrown side of the main fault because control is too meager.

ORIGIN, AGE, AND GROWTH OF THE VAN DOME

The genetic history of the Van dome indicates that it is underlain at great depth by an enormous mass of rock salt and that movement of the salt mass into a dome-shaped form has produced the uplift mapped in detail on the surface and in successively older formations to and including the top of the Comanche. All observations on the Van dome indicate that it is a salt dome in an incipient stage. The salt bed which underlies the structure at great depth has arched enough to uplift the overlying rocks more than 2500 feet above normal on the apex of the dome, but there is no suggestion of a salt stock. The dome has not reached a stage advanced enough for the development of a stock.

Criteria indicating that the Van uplift is basically a salt dome are:

1. Domal surface topography.
2. Radial drainage from the center of the topographic high.
3. Erratic surface dips and faulting in beds on top of the dome.

4. Areal distribution of formations and surface structural geology clearly depict a dome which definitely is not a part of a structural trend but a completely isolated quaquaversal uplift.
5. Structural mapping of all subsurface formations down to and including the top of the Comanche indicate a deep-seated salt dome.
6. Faulting on the Van dome is typical salt-dome faulting. Maximum displacements are on top of the dome, and there is a gradual decrease in throw toward the sides. Practically all faulting is confined to the immediate top of the dome.
7. The radial arrangement of minor faults outward toward the southeast from the main up-to-the-southeast fault on the upthrown flank and the concentric arrangement of faults on the original top of the dome northwest of the main fault indicate clearly that the forces responsible for the faulting came directly from below.
8. The presence of radial faulting on the upthrown southeast flank of the dome and the absence of such faulting on the top and on the north flank of the original dome indicate that the southeast flank was uplifted—the area of the original top of the dome northwest of the main fault did not drop—and as all faults on the dome are normal tension faults the genetic force must have come from directly beneath.
9. The intermittent or spasmodic growth of the Van uplift is typical of salt dome development.
10. A magnetic minimum overlies Van dome and theoretically should be expected because salt is normally less magnetic than other types of rock that should be present in the region.
11. A gravity minimum overlies Van dome and theoretically should be expected because salt is normally lighter in specific gravity than other types of rock which may be expected in the region.
12. Refraction seismograph survey of the Van area showed this uplift, which geographically is well down in the East Texas basin, to be completely isolated from any regional structural trend or line of folding. Geologic observations confirm this fact.
13. The salinity of water in the Woodbine formation on Van dome is exceptionally high in comparison with Woodbine water from normal structural areas similarly located in the embayment. It compares favorably with Woodbine salinity on definitely known salt domes.
14. Salt encrustation has been observed in cores from producing wells on the highest part of the structure which have never shown salt water and are bottomed from 50 to 100 feet above water level. Cores from the Eagle Ford and the Austin have also become encrusted with salt when left to dry in the sun.

The salt mass which undoubtedly underlies Van and is primarily responsible for the dome is at great depth, doubtless below the Comanche. There is nothing to indicate that great sedimentary salt beds were laid down in the Comanche, and the chief source which has been suggested in the past, the Glen Rose anhydrite section, has been drilled through in Van, in other areas in east Texas, and in Louisiana, without sedimentary salt beds being found. The main sedimentary salt series which seems to be a common source for the salt of the interior domes of Texas, and probably Louisiana, is without much doubt pre-Cretaceous. Some have suggested that the original sedimentary salt source is Permian. Since the Permian is a world-wide salt-bearing deposit this might be accepted if violence did not have to be committed on the paleo-geographic and paleo-geologic history of the region. There is little evidence to support Permian deposition in east Texas; most evidence is to the contrary. Possible salt sources remaining for the original sedimentary deposit are Triassic, Jurassic, and Paleozoic beds earlier than Permian. Triassic and Jurassic may be found under the center of the East Texas embayment, but they must change a great deal from their character in other parts of the world if they are to be the source of the enormous deposit of salt which has contributed to the forming of the salt domes of east Texas.

Of the older Paleozoics, the Silurian possibly is the most favorable source. It is a world-wide salt-bearing deposit and could be expected to carry enough saline rock to be a source for all the interior domes of east Texas and Louisiana. Furthermore, early Paleozoic rocks are known to be in close proximity to the East Texas embayment as they have actually been encountered along the Balcones fault zone in east Texas, the Ouachita Mountains in southeastern Oklahoma, and on uplifted areas south of Red River in northeastern Texas.

The structural history of the Van dome during Comanche time is almost unknown. From that part of the Comanche which has been penetrated in drilling on the structure, and by comparison of this information with data on the Comanche section of the surrounding territory, it appears that there was little if any uplift at Van until about the close of Comanche time. Furthermore, at the close of the Comanche, little if any erosion took place, though the Van area was being uplifted and faulted to some extent. The copper-colored and gray sandy shales found beneath the Woodbine on top of the Van dome are characteristic beds of the Grayson (uppermost Comanche in east Texas). Their character, thickness, and fossil content remain constant over a widespread area covering much of the East Texas basin. At Kelsey in Upshur County, in many localities in and adjacent to the East Texas oil field where a complete section is preserved, at Boggy Creek field in Anderson and Cherokee counties, at Long Lake and at Cayuga fields in Anderson County, at Opelika in Henderson County, and in other places there is ample evidence to show that extremely little if any Comanche has been eroded from the top of the Van dome.

The principal reason for thinking there was upward movement at Van in late Comanche time is the slightly greater displacement of faulting in the Comanche in comparison with faulting in the Woodbine and the slight thinning of the Woodbine over the Van structure, though it is possible to explain the thinning of the Woodbine by uplift which had its inception during Woodbine deposition. Van apparently was not a pronounced structure at the close of the Comanche, but there was probably a little uplift.

During Woodbine time 100 feet less section was laid over the Van dome than was deposited in the surrounding territory. No particular part of the formation appears to be absent, so the apex of the dome was not subject to erosion.

Eagle Ford time was a period of reasonably rapid growth for the Van dome. The Eagle Ford is thin over the top of the dome, only 175 feet out of a normal 425-foot section being present. This is further confirmed by the gradual pinching out of the sub-Clarksville sand zone in the Eagle Ford over high areas on the dome. Accompanying the uplift was considerable faulting especially along the main northeast-southwest trending fault. Absence of the sub-Clarksville over a large area on the upthrown side of the fault, together with a decided thinning of the Eagle Ford section over the same area, indicates that the south flank of the Van dome was being faulted upward while the entire dome was rising. On the actual top of the dome proper, which lies northwest of the main fault, the Eagle Ford is also thin and the sub-Clarksville pinches out around its flank. Relatively thick sections of Eagle Ford against the downthrown side of the main fault suggest the presence of enough displacement to influence deposition.

About two-thirds of a normal Austin section is found on top of the Van uplift, and its deposition seems not to have been affected by local irregularities on the dome, such as the main up-to-the-southeast fault. This suggests that faulting which occurred during Eagle Ford time was gradual, practically keeping pace with deposition; otherwise distinct evidence of unconformity should be found within the formation, and there would be truncation instead of gradual up-structure thinning of the sub-Clarksville as well as the Eagle Ford.

As the Austin has not been zoned, it cannot be definitely stated if any particular part of the section is missing; rather it is suspected that a thinner section on the top of the dome represents a fuller section off structure. From the close of the Austin to the beginning of Navarro time there was a gradual cessation of movement at Van culminating in stability during the upper Taylor. The lower Taylor is 800 feet thick on top of the dome in comparison with 925 feet off structure; the Pecan Gap is 130 feet thick over the top of the dome in comparison with 150 feet off structure, but the upper Taylor holds its normal thickness of 400 feet across the uplift.

At the beginning of Navarro time the dome again became slightly active as shown by thinning of the Navarro from 300 feet off structure to 250 feet on top of the dome. But it was not enough to affect the deposition of the Nacatoch sand in the Navarro as it did the sub-Clarksville sand in the Eagle Ford. The rate of uplift increased during the Midway while there was 650 feet of section laid down on top of the dome in comparison with 900 feet outside the area of uplift. This upward movement continued into Wilcox and later time permitting only 300 feet of Wilcox to remain at present on the top of the dome in comparison with a 1100-foot section outside the area of uplift. Non-deposition and later truncation are both responsible for thin Wilcox over the top of the Van dome.

Comparison of the several structural maps in regular geologic sequence, especially if an analysis of movement along faults is made, will afford a fairly detailed and accurate history of the structural growth of the Van dome.

TIME OF ORIGINAL OIL AND GAS ACCUMULATION

If it is assumed that all oil and gas in the Woodbine formation in the East Texas embayment were generated from a common source and that migration took place about the same time all over the embayment, some clue may be obtained as to the age of original migration into structural reservoirs of oil and gas in the Woodbine basin. It is not unreasonable to make such assumptions since the East Texas embayment in a broad sense is a great structural unit and the Woodbine formation in it is a regionally uniform, persistent deposit. Therefore, facts which are observed at one locality should be applicable to another locality within the basin.

Oil and gas in the East Texas field came into its present structural reservoir during or after Austin time because the Austin, lying across the truncated edges of the Eagle Ford and Woodbine and lapping onto the Comanche of the Sabine uplift, forms the "cap" which holds the oil and gas in place. Since it would have been necessary for the Austin to have some thickness and consistency in order to form an effective "cap," it probably was not called upon to serve in such capacity until most or all of it was laid down and was fairly well consolidated. This would be not before the close of Austin time and might well be considerably later. Therefore, if the assumptions are correct, oil and gas in the Woodbine formation in the East Texas embayment did not migrate into their original reservoirs until near the close of the Austin or later.

Kelsey structure in Upshur County and Opelika structure in Henderson County are relatively young. There is no geological indication of their presence prior to Wilcox time,[11] and neither one of them has had the slightest showing of oil or gas, though Kelsey has been tested to the anhydrite section of the middle Glen Rose, and Opelika has been tested to the top of the Comanche. Both of these structures are domed anticlines with incidental faulting and are of ample magnitude to have trapped oil and gas if they had been present when migration of oil and gas in the Woodbine took

[11]Reflection seismograph work on the Opelika structure does show divergence of interval between the Pecan Gap and the Austin, between the Austin and the Woodbine, and between the Woodbine and the Comanche outward from the top of the Opelika anticlinal dome This suggests continued uplift from Comanche time at least to Pecan Gap time. But these reflection data are hard to reconcile with geological information.

place. This suggests that oil and gas in the Woodbine in the East Texas basin migrated into its original structural reservoirs before Wilcox time. Consequently the migration is dated as taking place between the close of Austin and the beginning of Wilcox time. In this connection it is interesting to speculate as to how young a structure in the East Texas basin can be and still capture Comanche oil and gas. Saturation in the Paluxy and in the lower Glen Rose limestone section in Davis 6-T-1, 1000 feet structurally lower than the top of the Van dome, suggests commercial production in the Comanche on the top of the dome.

ORIGINAL AND PRESENT RELATION OF OIL AND GAS ACCUMULATION TO STRUCTURE ON THE VAN DOME

Wells drilled into the Woodbine formation on the Van dome outside the productive limit of the formation suggest that structural movement of the dome subsequent to the original accumulation of oil and gas in it has readjusted the oil and gas to the modified structure (Pl. 25).

Evidence has been presented previously in this study to substantiate the statement that the original top or apex of the Van dome is around lease 500, approximately 1 mile northwest of the upper trace of the main northeast-southwest fault in the Woodbine. Immediately southeast of this fault trace is the present highest structural area on the dome. To establish further the original top of the dome around lease 500, the gas accumulation is cited. In this area there is found the only free gas accumulation in the Woodbine in the Van field. and the area itself is, on the top of the Woodbine, 450 feet lower structurally than the top of the Woodbine on the southeast side of the main fault. The structurally higher area on the southeast side of the main fault has no free gas; all gas in this area is in solution in the oil. Apparently gas and oil accumulated normally in the Van dome when its apex was near lease 500, and some of it has been retained there by southeast and south dip toward the main fault. This fault later elevated a portion of the southeast flank of the dome structurally higher than the original apex. The main northeast-southwest fault, upthrown to the southeast. cuts across the dome just southeast of, and down the flank from, the gas cap and original top of the dome. Were the fault located farther to the northwest and had it cut through the gas area at the apex of the dome, the gas would have migrated to the upthrown, higher area south of the fault and would have formed a gas cap in that locality. Since the displacement of the fault in the Woodbine in the west-central part of the dome is not as great as the thickness of that formation, the Woodbine on the downthrown side of the fault is in contact with the Woodbine on the upthrown side of the fault at an elevation above the water level of the field. This has permitted ready migration of oil from the northwest or downthrown side to the southeast or upthrown side of the fault. However, this migration was confined to the area outside of the closure still remaining around the original top of the dome. That the area outside of this closure has been drained since the original accumulation, is evidenced by residue oil still left in the Woodbine below the present water level of the field over a region nearly as large as the present productive limit of the field. On the southeast side of the main fault, the original limit of accumulation seems to coincide with the present outline of production, suggesting that the additional reservoir space needed for the migrated oil was mainly obtained by elevating previously unsaturated portions of the Woodbine, which lay below the original water level, to a higher altitude and possibly pushing outward the original southeastern limit of accumulation. Such a migration or adjustment of oil to structure would not involve active water passage through the sand of the abandoned area of saturation, resulting in a considerable amount of residue oil yet remaining in the drained region. Time may also be an important factor in completing migration of oil, and this adjustment at Van may be too recent to have the process entirely completed. The time of this adjustment of oil and gas to the changed structure and the duration of the migration are not known. This readjustment of oil to structure has reduced the original area of accumulation by one-half and has greatly increased the thickness of the producing horizon of the Woodbine south of the main fault.

The gas area or cap at Van is relatively small, but this is to be expected in view of the fact that in the Woodbine in the northern part of the East Texas embayment conditions were more conducive to the formation of oil than gas. This is shown by the small amount of gas in relation to oil in the Mexia, Wortham, Powell, Van fields and in the East Texas field with the exception of its extreme southern end. Furthermore, gas in excess of oil is found in the Groesbeck, Red's Lake, Cayuga, Boggy Creek, Long Lake, Buffalo, Camp Hill fields and in the south end of the East Texas field. The field being developed in the Woodbine southwest of Rusk in Cherokee County has not been sufficiently explored to determine its gas-oil ratio.

There seems to be a definite relation between increase of gas over oil in the Woodbine formation in the East Texas basin, and the increase in the amount of shale in the formation, which in the gas area is predominantly gray and black instead of mottled red, white, green and blue, as it is in the oil area. Inquiry into the accumulation of oil and gas in structures in the Woodbine basin has led to the conclusion that the major faults which limit on the west the fields of the Mexia-Powell fault line have had little or nothing to do with the original accumulation of oil and gas in those structures of which they are a part. It is believed that the major faults which limit these fields on their western sides, as well as the minor faults within the fields themselves, are only incidental to folding which actually trapped the oil. The structures are really faulted anticlines. Evidence that substantiates this conclusion is found in the anticlinal axes of these so-called fault structures. These axes lie east of, on the upthrown side of, and on the regional dip side of the faults. The distance from the anticlinal axes to the faults varies in different fields as has been observed by Lahee[12] and others. In some localities the anticlinal axis in the Woodbine is practically against the trace of the fault on the top of that formation; in others it is 2000 to 3000 feet to the east of the fault. In this connection it should be stated that on many Woodbine structure maps, contouring has been carried down the face of the main Woodbine fault to the bottom of the formation as if it were the top of the Woodbine. This error in identifying the contour horizon enhances the west dip into the faults bounding the fields on their west sides.

---

[12]Lahee, F. H., Oil and gas fields of the Mexia and Tehuacana fault zones, Texas, *in* Structure of Typical American Oil Fields, vol 1, pp. 303–388, 1929.

However, after eliminating this error there is still a decided dip toward the main faults which cannot be explained by drag downward into the faults. It is believed that these fault-line fields overlie high areas in the pre-Comanche rocks, that they were originally long anticlinal folds which faulted near the top of their western flank, that the dip into or toward the faults which cut the west flanks is part of the original west dip of the folds, though it may have been steepened by actual drag, and that the west dip away from the faults on the west sides of the faults is a continuation of the normal west dip of the west flanks of the anticlines.

The effect which the major faults of the fault-line fields have had on oil and gas accumulation in the Woodbine is thought to be negligible; they may, however, have modified the structures so that readjustment of oil and gas took place in the structures, and further they doubtless permitted oil and gas to escape from the Woodbine into overlying beds.

It is fairly conclusive that in the East Texas embayment, structures must have been in existence before Wilcox time in order to have trapped Woodbine oil and gas, yet Lahee[13] in a most detailed study of the North Currie structure has definite proof that the main fault occurred during Wilcox time. Therefore, the structure should have had no oil or gas in the Woodbine, but the Woodbine did carry commercial quantities of oil and gas in the North Currie field. It is therefore believed that information obtained in recent years by drilling structures in east Texas, where their age is more definitely known, when applied to an analysis of fault line tectonics and structural history, shows that something other than faulting, with accompanying incidental closure, is responsible for accumulation of oil and gas in the fault-line fields.

On the Mexia structure there is evidence that between 250 and 300 feet of fault displacement occurred after the Navarro was deposited and before the Midway was laid down. During Wilcox time movement along the fault again took place to the amount of an additional 250 to 300 feet. This later movement coincides, accidentally perhaps, with a marked uplift at Van. On the Mexia structure, since the major fault displacement in the Navarro is

---

[13]Lahee, F. H. *op. ci* . p 316.

identical with the fault displacement in the Woodbine, the major fault cutting along the west side of the structure did not originate until after Navarro time, yet there is thinning of the Austin and Eagle Ford sections over the Mexia structure indicating that uplift was taking place before the major fault existed. Primarily the Mexia structure is anticlinal, and now it is a faulted anticline.

PRODUCING AND POSSIBLE PRODUCING HORIZONS AT VAN

Gas and oil are being produced from the Woodbine formation throughout the Van field proper. Small shallow production is being obtained from the Nacatoch and from basal Midway sands in what is known as the Brannon district on the north flank of the Van dome.

The Woodbine production is considered to be indigenous to the Woodbine formation, and the major part, if not all, of the shallower production or saturation in beds above the Woodbine is thought to have its origin in the Woodbine. Accumulation of oil and gas in beds overlying the Woodbine on the Van dome is invariably associated with faulting and restricted to areas where migration from below is apparent. In fact it is further believed that all production or saturation of beds younger than Woodbine age in the East Texas basin proper has its source in the Woodbine. Practically every place in the East Texas basin which is underlain by Woodbine where production is obtained from beds younger than the Woodbine, or where such beds have showings of oil and gas, there is either production or saturation in the Woodbine adjacent to or below these younger beds. This shallower saturation, accumulation, or even production, does not necessarily overlie directly production in the Woodbine, but it is not far removed, and the discrepancy in position can easily be explained by change in the present position of structure over its past location.

In the Brannon district at Van, shallow production is found well outside the productive limit of the present Woodbine field and accumulation but well within the area of original accumulation of Woodbine oil. Along the fault-line fields from Groesbeck to Powell, shallow production and showings are directly associated with the structures which contain Woodbine oil and gas. At Powell there is more discrepancy than in the other fault-line fields, but were the original position of the Woodbine structure known and the conditions under which the shallow accumulation took place apparent, it would be obvious that the source of the shallow oil and gas was from the Woodbine. Small faults and lensing sands appear to control shallow production in the Corsicana-Powell region away from the shallow accumulation which is associated directly with the fields themselves. Accumulation under such conditions and types of structures is thought to be the same as the accumulation in the Brannon district on the Van dome.

Practically every producing field of the Woodbine basin. including the fault-line fields, is faulted, thus permitting oil and gas from the Woodbine to escape upward into younger beds. The degree of saturation of the overlying beds seems to have a direct relation to the amount of faulting on the structures. If oil and gas in beds younger than the Woodbine were indigenous to these younger beds, there would have been shallow production on such structures as Kelsey, Opelika, and others which are too recent to have trapped Woodbine oil but certainly are old enough to have caught Nacatoch oil if it were indigenous to that horizon. In the fault-line fields progressive decrease in gravity of oil in beds consecutively above the Woodbine, over the Woodbine gravity, might be used as an example of loss of gravity in upward migration, were it not for the fact that being younger, these beds should normally contain heavier gravity oil than the Woodbine. At Van, in the Austin, Pecan Gap, and even in the Nacatoch on the top of the dome, within the present Woodbine accumulation area, gravity of oil found in saturated zones contiguous to faulting is often as high as in the underlying Woodbine. This may be due to the fact that migration from lower to higher beds above the Woodbine is continually taking place at Van, thus renewing the life and gravity of the shallower horizons as their oil and gas are dissipated upwards.

Production from the Austin and Pecan Gap chalks within the present area of Woodbine accumulation will be obtained at Van along faulted and fractured zones where reservoirs have developed and from the Nacatoch and basal Midway sands in areas adjacent to faulting where these sands are saturated from below. Such shallow production will be erratic and should be considered only after the drilling program for Woodbine production has been completed. From records of these Woodbine wells, an outline can be made of the possible productive area of the various shallower horizons. Production from the sub-Clarksville sand will be small and will be confined at least within the outer limits of Woodbine production. Over much of the top of the structure the horizon is absent.

Below the Woodbine formation at Van there are several possible producing horizons in the Comanche, especially the Paluxy and Glen Rose, where indications of oil have already been obtained in a test located outside of the possible productive area. The Van dome, because of its great age, magnitude, gently sloping flanks, location near the axis of the East Texas embayment where an enormous thickness of sedimentary rocks may be expected, the great depth to the probable salt mass underlying the dome, its present production, its showings from the Comanche in an unfavorably located test, sand bodies and other porous horizons already penetrated in drilling, is one of the most desirable places for a proper test of the Comanche formations.

DRILLING METHODS

As outlined in the original unitization agreement of November 1, 1929, The Pure Oil Company has carried on all development in the unitized area. An advisory board representing all interested companies consults with the operators regularly about development problems.

All wells in the Van field have been drilled with rotary equipment. Fuel oil was used to fire the boilers in drilling the discovery well; subsequently gas from the field has been used for all fueling purposes in the field. There is ample clay in all formations so that mud is made as the holes are drilled. Drilling is carried on in a leisurely manner; the average time for completing a well to depths of around 3000 feet is three weeks. With this type of a drilling program ample time is had for careful sampling, coring, surveying for deviation, and making Schlumberger surveys.

Because of soft loose sand in the Wilcox at the surface, the faulted and fractured nature of formations overlying the dome, and the escape of oil and gas from lower to higher beds, surface casing is usually set at about 300 feet and is cemented throughout its entire length. A depth of 300 feet usually is sufficient to penetrate to the basal shaly part of the Wilcox or reach the tough Midway shales below the Wilcox.

The only other casing set is a 7-inch O.D. production string which is seated and cemented at the top of the Woodbine. From 200 to 400 sacks of cement are used to cement off, protect, and preserve upper formation which in places will produce.

Because the maximum rock pressure in the field is about 1300 pounds per square inch, casing, tubing, and connections are mill tested to 1300 pounds. Tubing, either 2 or 2½ inches in diameter, is used for flow-strirgs and is generally swung about 20 feet above the bottom of the hole inside 5 3/16-inch perforated liners. The tubing is swung off bottom because in some wells the softer beds of sand in the Woodbine gradually work through the perforations in the liner and settle to the bottom of the hole.

When tubing is swung, the christmas tree is in place, and connections are made to tank batteries, wells are washed free of mud and then swabbed into production. In the early months of the field, wells were cleaned into mud pits from which the cut oil was pumped into trucks for oiling roads. Later practice has been to clean wells through a large separator and then switch to flow tanks. This eliminates loss of oil, decreases hazards, and increases the neat appearance of the field. When a well is completed all drilling equipment is removed except the derrick which is taken down only where it may be a hazard, mud pits are filled, and all refuse is removed. The ground is then graded, giving the field the appearance of producing only gas. This development practice has reduced hazards to a minimum. A field geologist superintends the sampling, coring, logging, and casing seat selection of each well. This results in an accurate record of all formations and their producing possibilities and insures a consistent casing program.

PRODUCTION METHODS

Throughout most of the Van field all gas is in solution in the oil, and consequently it is possible to choke wells having an estimated open flow capacity through casing of 50,000 barrels or more a day to as low as 25 barrels a day without disturbing the original low gas-oil ratio. Thus they can be flowed continuously and remain within their allowable. This is better engineering practice than to flow them spasmodically, and it greatly simplifies equitable proration. The average gas-oil ratio in the Van field is 325 cubic feet of gas per barrel of oil produced, the highest ratio being 385 cubic feet of gas per barrel and the lowest 260 cubic feet per barrel. Production tests for proration purposes are taken for three consecutive hours through 2½-inch tubing and 11/16-inch choke. This method does not indicate the actual potential of the well being tested but only its comparative performance with other wells in the field.

Oil from the Van field is run to the Pure-Van tank farm (capacity 550,000 barrels) just northwest of the field and to the Humble Pipe Line Company tank farm (capacity 185,000 barrels) northeast of the field. From the Pure-Van tank farm a 10-inch line having an estimated capacity of 55,000 barrels a day delivers the oil to Smith's Bluff Refinery of The Pure Oil Company. The Humble Pipe Line Company runs its oil through a 10-inch line having a daily estimated capacity of 35,000 barrels to Shreveport, Louisiana. Oil was run through this line for the first time on December 27, 1930. The Pure-Van line to Chandler, 17 miles southeast of the field and on the St. Louis and Southwestern railroad, first delivered oil on December 14, 1929. Later this line was extended to the Smith's Bluff Refinery of The Pure Oil Company, and oil was first delivered to the refinery by pipe lines on July 11, 1930.

GAS AND GASOLINE PRODUCTION

A modern gasoline plant was installed in the Van field on July 15, 1930, before much development had taken place in the field. Wells are flowed continuously through oil and gas separators from which the gas is taken at atmospheric pressure to the gasoline plant located on the west edge of the field. There by compression and absorption the gasoline is taken out of the gas and is loaded into tank cars for sale or shipment to Smith's Bluff Refinery of The Pure Oil Company. The residue gas is sold to The United Gas Company which built a gas line into the Van field in May, 1933. Gasoline in the gas obtained from wells in the Van unit averages about two gallons per thousand cubic feet.

OIL PRODUCTION

The entire Van field, comprising the Van unit area and the Carroll district which includes the remainder of the Woodbine productive area not in the Van unit, has been under proration since its discovery. The following yearly production record is therefore not an index of the capacity of the field to produce but is merely its allowed production.

Year	*Barrels*
1929 (from date of discovery, November 13)	150.131
1930	7,717,774
1931	15,712.006
1932	17,321,231
1933	17,225,296
1934	14.732,400
1935 (to September 1)	9,783,032

Total accumulated production of Van field to September 1, 1935, is 82,641,870 barrels.

The above production tabulation includes a negligible amount of oil produced from Midway and Navarro sands in the Brannon district, on Van dome, north of the Woodbine producing area.

The gravity of Woodbine oil in the Van field varies considerably, ranging from 32° to 40° gravity A.P.I. The reported weighted average is 35° gravity A.P.I. The shallow oil of the Brannon district averages 31° gravity A.P.I. The oil from both the Woodbine and the shallower horizons is paraffin base, and the color ranges from dark olive-green and very dark green to greenish black.

ANALYSIS OF WOODBINE OIL FROM THE VAN FIELD

The following is an analysis made by L. M. Henderson of crude oil from Smith's Bluff Refinery:

Gravity, 34.8; flash, R.T.; pour, O; B.S.&W., 0.1%; vis/70, 67; vis/100, 50.5; sulphur, 0.98%; water, 0.08%; color, black; charge, 2000 c.c.

Cut No.	Column Head Temp. °F.	Per cent Cut	Pour Point	Vis/100	Vis/130	A.P.I. Gravity
Initial	below 150					
1	160	5				
2	222	5				
3	265	5				
4	308	4				
5	326	2				
6	333	2				
7	370	2				
8	385	2				50.4
9	401	1				48.5
10	408	1				48.2
11	410	1				47.4
12	425	1				46.4
13	430	1				45.4
14	442	1				44.5
15	455	1				40.8
16	467	1				41.6
17	482	1				41.6
18	490	1				41.1
19	497	1				40.9
20	505	1				39.1
21	511	1				38.6
22	511	1				36.9
23	515	1				36.1
24	528	1				36.0
25	538	1				36.0
26	557	1.0				36.0
27	575	1.5				35.5
28	600	1.5	20	43.5		34.1
29	627	2.0	30	47.5		32.0
30	650	2.5	35	53.3		30.4
31	662	2.5	35	60.6		29.5
32	687	2.5	40	67.7		29.2
33	725	2.5	55	85.6		28.7
34	730	2.5	65	112.2		27.8
35	757	2.5	65	132.5		26.4
36	772	2.0		257.2		25.5
37	Steam	2.5		320.0	153.6	24.5
38	"	2.0			188.7	23.2
2nd recovery		0.1				
Bottoms		27.7				13.6
Loss		0.7				

Yield Summary

	Vol. %	Grav	Viscosity	Sulfur %	Octane No.	Et_1–70	Pour	Flash	Fire	Vis. Grav. Const.
300 E. P. gasoline	19.0	68.7	—	—	47.5	3.8	—	—	—	—
350 E. P. "	24.0	65.1	—	—	43.0	4.8	—	—	—	—
400 E. P. "	29.0	62.2			38.4	More than 5 c.c. ET_1 — 70				
410 E. P. "	30.0	61.4	—	—	37.5	" " " " " "				—
420 E. P. "	31.0	60.7	—	.04	36.5	" " " " " "				—
350 Th. Vis. kerosine	18.0	48.1	350 Th. Vis.	—	—	—	—	122TCC	—	—
375 Th. Vis. kerosine	20.0	46.9	375 Th. Vis.	—	—	—	—	124TCC	—	—
400 Th. Vis. kerosine	22.5	45.6	400 Th. Vis.	—	—	—	—	126TCC	—	—
Kerosine distillate or furnace oil	9.0	43.3	525 Th. Vis.	.05	—	—	—	198PM.	—	—
Cracking stock	6.5	36.4	—	—	—	—	—	—	—	—
Wax distillate	25.1	27.6	96/100	—	—	—	+60	365	390	.810
Bottoms	27.7	13.6	789/210 SU				+60 min	575	650	.887
Loss	0.7	—	1500 Fu/122							

A. S. T. M. Distillations

Per cent recovered

Product	IBP	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	E. P.	Per cent Rec	Per cent Res.	Per cent Loss
300 E. P. gasoline	96	138	155	172	189	204	220	232	246	262	277	290	300	98.0	0.8	1.2
350 E. P. "	96	139	160	189	210	230	250	265	280	298	319	335	352	98.3	1.1	0.6
400 E. P. "	106	151	172	199	224	248	271	289	317	339	363	380	398	98.5	1.0	0.5
410 E. P. "	106	151	173	200	226	253	275	297	320	347	370	387	410	98.5	1.0	0.5
420 E. P. "	108	152	173	205	230	257	280	300	325	350	377	398	422	98.5	1.0	0.5
350 Th. Vis. kerosine	332	347	353	363	376	389	401	417	430	445	460	473	480	98.3	1.3	0.4
375 " " "	337	350	357	370	383	397	410	426	440	454	473	485	496	98.3	1.3	0.4
400 " " "	342	354	360	373	387	400	416	433	446	460	478	493	510	98.5	1.2	0.3
Kerosine distillate	427	437	442	446	449	453	457	463	469	477	489	495	507	98.8	1.0	0.2

The complete wax distillate (25.1%) was of poor pressing quality.

The yield of good pressing wax distillate of relatively low wax content was 18.5%.

PRESSURE DECLINE IN THE VAN FIELD

Bottom-hole pressures have been taken in the Van field only during the past three years, so the original bottom-hole pressure is not known. Surface casing pressures of gas wells before they began flowing oil in the top of the Woodbine formation on leases 500, 9, and 10 were measured, and they averaged 1300 pounds per square inch. Subsequently, original pressures were calculated from later observed bottom-hole pressures using decline curves established over a period of bottom-hole pressure observations. These calculated original bottom-hole pressures for a depth in the Woodbine of 2400 feet below sea level were 1299 pounds per square inch.

Pressure declines in the Woodbine in the Van field vary considerably depending on whether a well is completed in the upper or bentonitic part of the Woodbine or in the lower non-bentonite or so-called brown-sand part of the formation. The bentonitic or upper part of the Woodbine is not constant in thickness over the field, but in general it averages 250 feet. Permeability in the bentonitic part of the section is considerably lower than in the brown-sand part of the section; consequently bottom-hole pressures in the lower permeable part of the formation are sustained by water drive, whereas in the less permeable upper part of the Woodbine the water cannot pass readily through the bentonitic cementing material, and bottom-hole pressures drop if wells are flowed at a rate which is in excess of the penetration of water into the sand. The Woodbine water head is constant where encountered around the Van field and rises to within an average of 250 feet of the surface.

Bottom-hole pressure maps and pressure decline maps have not been included in this study because the constant change in pressure in the field renders them obsolete in a relatively short time.

WATER ENCROACHMENT IN THE VAN FIELD

Edge water was encountered early in the development of the Van field while delimiting the productive area. Bottom-hole water was encountered in a few wells which were drilled to establish the original water level or table in the Woodbine, so that a uniform and satisfactory completion depth for wells in the field could be determined. The original water level in the Woodbine in Van was 2507 feet below sea level, and it was found to be uniform, constant, and identical over the field. With this information available it was decided to drill wells and complete them within 50 feet of the water level, unless they were edge wells in which the Woodbine would not be encountered sufficiently above that depth to produce commercially. Such edge wells have been drilled slowly and tested, even below minus 2450 feet, until they either produced commercially or proved to be non-productive and were abandoned.

Water encroachment in the Van field has been gradual and as expected. Some wells a considerable distance inside of the edges of the field are producing bottom-hole water, but all such wells are definitely located on faults which are clearly responsible for such irregular occurrences of water in the field.

PRORATION METHODS

Acre-feet of Woodbine formation under each individual lease, together with the balancing of offset wells, has been the basis of proration in the Van field from its discovery until April 1, 1935. This method approached the ideal, namely, to give each lease owner the oil which he was actually entitled to have under his lease. In the present proration method 50 per cent is accorded to acre-feet of Woodbine formation above water level under each lease and 50 per cent to static bottom-hole pressure under the lease—the pressure factor theoretically compensating for structural position of wells and leases. The minimum allowable for any well in the field is 25 barrels a day.

AVERAGE DAILY ALLOWABLE UNDER PRORATION

The Van field has been strictly prorated as to production since the discovery well was completed. Previous to October 19, 1931, production was regulated by The Pure Oil Company and the Humble Oil and Refining Company which controlled the outlet through their pipe lines. On October 19, 1931, the Railroad Commission of the State of Texas assumed jurisdiction of the field allowable and since that time have granted the following allowables:

Date	*Barrels per day*	*Date*	*Barrels per day*
October 19, 1931	50,000	October 18, 1933	38,850
September 15, 1932	45,000	October 30, 1933	37,500
October 15, 1932	42,500	April 12, 1934	42,500
December 1, 1932	45,000	May 12, 1934	45,500
December 10, 1932	42,500	June 12, 1934	47,500
January 1, 1933	41,500	July 1, 1934	42,750
January 25, 1933	52,450	October 1, 1934	34,200
September 1, 1933	39,620	December 1, 1934	37,200
October 1, 1933	39,225	December 18, 1934	42,750

SALT WATER DISPOSAL SYSTEM

Salt water is collected by gravity gathering lines from tank batteries and local pits and is delivered into a two-million barrel earthen storage pit which has been excavated just northeast of the field. Water is here impounded and a considerable amount evaporates during the dry season. When Sabine River is in flood, salt water from the storage pit is turned into it through a dry creek. The distance from the pit to the river is 7 miles.

The following analyses of samples of salt water from the Woodbine formation in the Van field indicate the extremely high saline content of the water as compared with salt water in other Woodbine fields not associated with salt domes and the similarity to salt water from the Woodbine in Boggy Creek where a salt mass is present and at a shallow depth.

The buoyancy of the Woodbine water in the salt water disposal pit at Van is equal to that of Great Salt Lake, Utah.

Analysis of a sample of salt water from the Woodbine formation at 3082 feet in Crim 28 No. 1 Well.

Properties of reaction in per cent:	
Primary salinity	92.32
Secondary salinity	7.30
Primary alkalinity	0.00
Secondary alkalinity	0.38
Per cent rSO4 in rSO4 plus rCl	2.66
Ratio RCO3 to RSO4	0.14
Constituents in parts per million:	
Sodium	25454.8
Calcium	1310.1
Magnesium	326.7
Iron and aluminum oxides	24.0
Sulphate	1530.8

Chloride	41250.0
Carbonate	141.6
Silica	36.0
Total	70074.0

Reacting values in per cent:

Alkalies—	
Sodium	46.16
Alkaline earths—	
Calcium	2.73
Magnesium	1.11
Strong acids—	
Sulphate (rSO4)	1.33
Chloride (rCl)	48.48
Weak acids—	
Carbonate (rCO3)	0.19

Hypothetically combined as	Parts per million	Grains per U. S. gal.
Calcium carbonate	236.0	13.76
Calcium sulphate	2171.0	126.57
Calcium chloride	1591.0	92.76
Magnesium chloride	1279.0	74.57
Sodium chloride	64737.0	3774.17

Analysis of a sample of salt water from the Woodbine formation at 2997 feet in Magers 18 No. 1 Well.

Properties of reaction in per cent:

Primary salinity	92.50
Secondary salinity	7.12
Primary alkalinity	0.00
Secondary alkalinity	0.38
Per cent rSO4 in rSO4 plus rCl	2.36
Ratio RCO3 to RSO4	0.16

Constituents in parts per million:

Sodium	27883.3
Calcium	1381.3
Magnesium	358.2
Iron and aluminum oxides	32.0
Sulphate	1489.6
Chloride	45250.0
Carbonate	153.6
Silica	32.0
Total	76580.0

Reacting values in per cent:

Alkalies—	
Sodium	46.25
Alkaline earths—	
Calcium	2.63
Magnesium	1.12
Strong acids—	
Sulphate (rSO4)	1.18
Chloride (rCl)	48.63
Weak acids—	
Carbonate (rCO3)	0.19

Hypothetically combined as	Parts per million	Grains per U. S. gal.
Calcium carbonate	256.0	14.92
Calcium sulphate	2106.0	122.78
Calcium chloride	1837.0	107.10
Magnesium chloride	1403.0	81.79
Sodium chloride	70914.0	4134.29

Analysis of a sample of salt water from the Woodbine formation at 3023 feet in Peters 29 No. 1 Well.

Properties of reaction in per cent:	
Primary salinity	92.40
Secondary salinity	7.26
Primary alkalinity	0.00
Secondary alkalinity	0.34
Per cent rSO4 in rSO4 plus rCl	2.74
Ratio RCO3 to RSO4	0.12
Constituents in parts per million:	
Sodium	27955.2
Calcium	1424.0
Magnesium	352.9
Iron and aluminum oxides	32.0
Sulphate	1736.5
Chloride	45250.0
Carbonate	134.4
Silica	64.0
Total	76949.0
Reacting values in per cent:	
Alkalies—	
Sodium	46.20
Alkaline earths—	
Calcium	2.70
Magnesium	1.10
Strong acids—	
Sulphate (rSO4)	1.37
Chloride (rCl)	48.46
Weak acids—	
Carbonates (rCO3)	0.17

Hypothetically combined as	Parts per million	Grains per U. S. gal.
Calcium carbonate	224.0	13.06
Calcium sulphate	2460.0	143.42
Calcium chloride	1693.0	98.70
Magnesium chloride	1380.0	80.45
Sodium chloride	71096.0	4144.89

A comparison of the analyses of water from the Woodbine formation at Van with analyses of waters from other areas of the Woodbine, and from different types of structure in the East Texas embayment,[14] furnishes interesting data for speculation.

[14]Plummer, F. B., and Sargent, E. C., Underground waters and subsurface temperatures of the Woodbine sand in northeast Texas: Univ. Texas Bull. 3138, 178 pp., 1931.

The following analysis is of a typical sample of water from the Woodbine formation in the Mexia field, Limestone County, Texas. It is a characteristic Woodbine water sample from the fault-line fields where no salt mass is known.

Analysis of a sample of salt water from the Woodbine formation at 3069 feet in R. E. Crouch No. 4 Well.

Properties of reaction in per cent:	
Primary salinity	91.70
Secondary salinity	6.96
Primary alkalinity	None
Secondary alkalinity	1.34
Per cent rSO4 in rSO4 plus rCl	.18
Ratio RCO3 to RSO4	7.4
Constituents in parts per million:	
Sodium	11350.3
Calcium	573.3
Magnesium	194.4
Iron and aluminum oxides	55.0
Sulphate	44.9
Chloride	18750.0
Carbonate	218.4
Silica	25.0
Total	31211.4
Reacting values in per cent:	
Alkalies—	
Sodium	45.85
Alkaline earths—	
Calcium	2.66
Magnesium	1.49
Strong acids—	
Sulphate (rSO4)	.09
Chloride (rCl)	49.24
Weak acids—	
Carbonate (rCO3)	.67

Hypothetically combined as	Parts per million	Grains per U. S. gal.
Calcium carbonate	364.0	21.12
Calcium sulphate	63.5	3.68
Calcium chloride	1135.2	65.72
Magnesium chloride	758.2	44.00
Sodium chloride	28812.5	1670.12

The following analysis is of a sample of typical salt dome Woodbine water from John Gouger No. 1 of the Humble Oil and Refining Company in the Boggy Creek oil field in Anderson and Cherokee counties, Texas.[15]

[15]McLellan. H. J., Wendlandt. E. A., and Murchison, E. A., Boggy Creek salt dome, Anderson and Cherokee counties. Texas: Bull. Amer. Assoc. Petr. Geol., vol. 16, p. 600, 1932.

Analysis of a sample of water from the Woodbine formation at 3955 feet in John Gouger No. 1 Well.

Radicals	*Parts per million*
Sodium	32,100
Calcium	3,790
Magnesium	528
Chlorine	57,500
Sulphate	247
Bicarbonate	232
Total	94,397

Comparison data	*Per cent*
Primary salinity	85.84
Secondary salinity	13.92
Primary alkalinity	--- ---
Secondary alkalinity	0.24
Chlorine salinity	99.60
Sulphate salinity	0.40

Ratios	
Chlorine: bicarbonate	426.00
Bicarbonate: sulphate	0.74
Calcium: magnesium	4.36
Sodium: calcium and magnesium	6.00

The following analysis is of a sample of water from the Paluxy formation in Davis 6-T-1 in the Van field between 4763 and 4851 feet. Sample taken from bottom of drill stem in drill stem test.

Properties of reaction in per cent:

Primary salinity	91.76
Secondary salinity	7.68
Primary alkalinity	0.00
Secondary alkalinity	.56
	100.00

Constituents	P.P.M.	Reacting value	Per cent reacting value
Total solids			
Iron and aluminum (na)	24,648	1071.44	45.88
Calcium (ca)	1,479	73.80	3.18
Magnesium (Mg)	272	22.36	0.96
Sulphate (so4)	330	6.86	0.29
Chlorides (cl)	40,931	1154.25	49.43
Carbonates (r_2O_3)	Trace	0.00	0.00
Bicarbonates (HCO_3)	396	6.49	0.28
	68,056	2335.20	100.00

The following analysis is of a sample of water from the Paluxy formation at 4725 feet in Davis 6-T-1, Van field.

Ions	*P.P.M.*
Ca	1,570
Mg.	314
Na	25,072
Cl	41.510
So_4	830
HCO_3	389
R_2O_3	6
SiO_2	40
Total	69,731

Total solids per 100 cc. filtered sample 9.3369 gms.
Volatile solids per 100 cc. filtered sample 2.6199 gms.

Two samples of water from E. L. Smith et al. Steubenrauch No. 1, Mexia field, Limestone County, Texas, from 5732 feet (in Trinity sand section immediately underlying the Gren Rose) contained 104,100 and 113,500 P.P.M. chlorine, respectively, which is about six times the chlorine content of Woodbine water in the same field and about twice as saline as Woodbine water from Boggy Creek salt dome where the salt stock reaches within 1600 feet of the surface.

FUTURE RECOVERABLE OIL RESERVE IN THE WOODBINE FORMATION IN THE VAN FIELD

Exhaustive studies were made of the Woodbine formation in the Van field as a basis for the final valuation of acreage held by the associated companies. All well records in the Woodbine were analyzed to determine the relative amounts of sand and shale in the formation. A remarkable uniformity of 50 per cent sand and 50 per cent shale was found throughout the field. Since all Woodbine sand in the field above the original common water table (2500 feet below sea level) over the entire field was saturated with oil and gas, the problem of valuation was somewhat simplified. Sand characteristics, porosity, permeability, and actual history of individual well performances were considered in a solution of the problem. Acre-feet of Woodbine formation under individual leases was the basis for the valuation. To obtain accurately the number of acre-feet of Woodbine sand under individual leases, the top of the Woodbine, including fault faces, was contoured on 20-foot intervals to minus 2500 feet or water level for the field (Pl. 21).

Planimeter calculations of individual leases gave the volume of Woodbine present under each lease above water level. The top of the Comanche, where it is found above minus 2500, was also contoured on 20-foot intervals (Pl. 22), and its volume under individual leases was determined. From these figures the actual number of acre-feet of Woodbine was calculated, the Comanche volume being deducted where these rocks reach above the Woodbine water level of the field. As 159 wells out of a total of 450 wells had been cored in the Woodbine at the time of the final valuation and as the drilled wells had been carefully logged and sampled, basic data are fairly accurate.

From a thorough lithologic analysis of the Woodbine section and the behavior of individual wells penetrating various parts of the producing horizon, the Woodbine is arbitrarily zoned into upper bentonitic, lower bentonitic, upper brown-sand, and lower brown-sand. Recoverable barrels of oil per acre-foot of productive formation were calculated for each zone over each lease.

PERCENTAGE OF PARTICIPATION IN THE VAN JOINT ACCOUNT OF VARIOUS COMPANIES ASSOCIATED IN THE UNIT

At the expiration of the first two and a half-year period from November 1, 1929, the interests were tentatively adjusted to conform more closely with actual percentages of producing acreage as outlined by development during the two and a half-year period. The revised percentages were:

Company	*Per cent*
The Pure Oil Company	77.06
The Texas Company	8.54
Shell Petroleum Corporation	8.16
Sun Oil Company	5.58
Humble Oil and Refining Company	.66

The final re-evaluation at the end of the first five-year period, as provided in the original contract and based on a thorough analysis of all data acquired, gave the following proportionate interests in the Van Joint Account or Van unit:

Company	*Per cent*
The Pure Oil Company	76.73
Shell Petroleum Corporation	9.18
The Texas Company	8.36
Sun Oil Company	5.18
Humble Oil and Refining Company	.55

Acreage held by The Pure Oil Company, Humble Oil and Refining Company, Shell Petroleum Corporation, and The Texas Company in the Van field but outside of the area included in the Van unit is operated individually and separately under the supervision of each company though in close coöperation with The Pure Oil Company which operates the unitized area for the associated companies.

WATER SUPPLY FOR THE VAN FIELD

Springs feeding the headwaters of Neches River 3 miles southwest of the Van field supplied water for camp purposes and for drilling during the early life of the field. An earthen dam across a small gulley impounded sufficient water for early development. Drouth and an increased demand for water for the gasoline plant, an active drilling campaign, and greater domestic use necessitated additional water.

A site for the drilling of large-diameter shallow-depth gravel-packed water wells into the Wilcox was selected 3 miles southeast of the field. because of the abundance of potable water on the flanks of the dome. Three water wells were completed to an average depth of 450 to 525 feet and were equipped with electrically driven centrifugal pumps. Their capacity, estimated between 20,000 and 25,000 barrels a day. is ample for any contemplated development in the field.

Water from these wells is pumped to a 55,000-barrel tank situated on a hill in the southwestern part of the field. From this tank a gravity network supplies all demand. The water is high in iron content, apparently derived from the ferruginous matter of the Wilcox beds from which the water comes.

COLLECTION AND PRESERVATION OF SAMPLES, CORES, AND GEOLOGICAL DATA

Samples are taken in drilling wells at 20-foot intervals in formations above the Woodbine; in the Woodbine the interval is reduced to 10 feet. Samples are caught in the mud ditch, are washed free of drilling mud, and are steam-dried at the well. There is no correction made for time lag in samples taken above the Woodbine. At the top of the Woodbine, timed samples are taken. The character of the basal part of the Eagle Ford indicates the proximity of the Woodbine. In drilling into the top of the Woodbine there is a noticeable change in speed of drilling. When the change is noted 5 feet more hole is made and then the bit is pulled up a foot or two off bottom and rotated with pumps running. The mud ditch is cleaned and circulation maintained for 30 to 60 minutes depending on the depth of the hole, mud pump speed and capacity, and size of hole. In the standard 9⅞-inch hole drilled to the Woodbine at Van the cuttings return at the rate of about 100 feet per minute for depths of less than 2400 feet. Below 2400 feet a little longer time is required for their return. These samples taken to determine the top of the Woodbine are labeled "timed samples."

Sample cuttings are sacked in the field laboratory, in manila sample envelopes for permanent filing. Associated companies are supplied with portions of the samples in labeled cloth bags. Formation contacts above the Woodbine are determined after samples are thoroughly washed, fossils picked, identified, and filed on slides for permanent record. All core material is carefully labeled and preserved in open core boxes in racks where the cores can be examined readily. Specially constructed core barns have been built in the field so the core records are readily available at all times. Weekly geological reports are furnished all associated companies. These include sample descriptions, formation contacts, and other geological data. Maps, cross-sections, and other geological studies incidental to the development of the field are prepared currently in the field laboratory by a resident field geologist.

VAN JOINT ACCOUNT UNITIZATION AGREEMENT

PURPOSE AND ACHIEVEMENTS

Since The Pure Oil Company, the Sun Oil Company, the Shell Petroleum Corporation. The Texas Company, and the Humble Oil and Refining Company owned and controlled oil, gas, and mineral leases covering what was thought might be the producing area of the Van oil and gas field, it was deemed advisable to explore and exploit the area jointly because of the resultant saving in cost of exploration and exploitation. Furthermore in the event of production it was believed that the development program could be carried on with maximum recovery of oil and gas at a minimum cost if the area of production could be operated as a unit. With this purpose in mind an outline (Pl. 27) of the probable productive area of the Van field was agreed upon, and all leases within the area of the unit operation previously held by the individual companies were in the future to be owned jointly by all participating companies based on the proportionate amount of acreage which each company held within the unitized area.

Transfers and assignments were made conveying to the other parties the several individual interests in the respective leases owned by each party since it was necessary to vest the ownership of all such leases jointly in the several parties hereto in the respective individual interests above set forth.

The result of this unit agreement has been the development of over three-fourths of the Van field (that part which was included within the area of unitization) at a minimum of cost and with a maximum recovery of oil.

Lease numbers in the Van field signify:

Numbers 1 to 99	The Pure Oil Company (Van Joint Account)
Numbers 100 to 199	The Pure Oil Company (Carroll district)
Numbers 200 to 299	Humble Oil and Refining Company (Van Joint Account)
Numbers 300 to 399	Shell Petroleum Corporation (Van Joint Account)
Numbers 400 to 499	Sun Oil Company (Van Joint Account)
Numbers 500 to 599	The Texas Company (Van Joint Account)
Numbers 600 to 699	Van Joint Account

Other leases in field outside Van Joint Account are indicated by company or individual names.

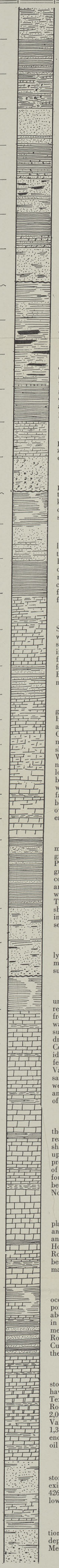
INDEX

Plate 2

Regional map of the east Texas geosyncline showing the surface outcrop of the Woodbine formation and the major structural features in east Texas. All contour lines are drawn on the top of the Woodbine formation except contouring of Mt. Enterprise structure in Rusk County which is contoured on the top of the Comanche. The outside contour approximates the limit of the structure. Stipple area represents surface outcrop of Woodbine.

System	Series	Group		Formation	
TERTIARY	EOCENE	JACKSON		FAYETTE	
TERTIARY	EOCENE	CLAIBORNE		YEGUA	
TERTIARY	EOCENE	CLAIBORNE	COOK MOUNTAIN	CROCKETT	
TERTIARY	EOCENE	CLAIBORNE	COOK MOUNTAIN	SPARTA	
TERTIARY	EOCENE	CLAIBORNE	MOUNT SELMAN	WECHES	
TERTIARY	EOCENE	CLAIBORNE	MOUNT SELMAN	QUEEN CITY	
TERTIARY	EOCENE	CLAIBORNE	MOUNT SELMAN	REKLAW	
TERTIARY	EOCENE	CLAIBORNE		CARRIZO	
		Unconformity			
TERTIARY	EOCENE	WILCOX		SABINETOWN	
TERTIARY	EOCENE	WILCOX		ROCKDALE	
TERTIARY	EOCENE	WILCOX		SEGUIN	
TERTIARY	EOCENE	MIDWAY		WILLS POINT	
TERTIARY	EOCENE	MIDWAY		KINCAID	PISGAH MEMBER
TERTIARY	EOCENE	MIDWAY		KINCAID	LITTIG MEMBER
		Unconformity			
CRETACEOUS	GULF	NAVARRO		KEMP	
CRETACEOUS	GULF	NAVARRO		NACATOCH	
CRETACEOUS	GULF	NAVARRO		NEYLANDVILLE	
CRETACEOUS	GULF	TAYLOR		UPPER TAYLOR	
CRETACEOUS	GULF	TAYLOR		PECAN GAP	
CRETACEOUS	GULF	TAYLOR		WOLFE CITY	
CRETACEOUS	GULF	TAYLOR		UN-NAMED MARLS	
CRETACEOUS	GULF	TAYLOR		GOBER	
CRETACEOUS	GULF	TAYLOR		BROWNSTOWN	
CRETACEOUS	GULF	AUSTIN		BLOSSOM	
CRETACEOUS	GULF	AUSTIN		BONHAM	
CRETACEOUS	GULF	AUSTIN		ECTOR	
CRETACEOUS	GULF	EAGLE FORD		SUB-CLARKSVILLE	
CRETACEOUS	GULF	WOODBINE		BENTONITIC PART	
CRETACEOUS	GULF	WOODBINE		NON-BENTONITIC PART	
		Unconformity			
CRETACEOUS	COMANCHE	WASHITA		GRAYSON	
CRETACEOUS	COMANCHE	WASHITA		MAIN STREET	
CRETACEOUS	COMANCHE	WASHITA		PAWPAW	
CRETACEOUS	COMANCHE	WASHITA		WENO	
CRETACEOUS	COMANCHE	WASHITA		DENTON	
CRETACEOUS	COMANCHE	WASHITA		FORT WORTH	
CRETACEOUS	COMANCHE	WASHITA		DUCK CREEK	
CRETACEOUS	COMANCHE	FREDERICKSBURG		KIAMICHI	
CRETACEOUS	COMANCHE	FREDERICKSBURG		"GOODLAND"	
CRETACEOUS	COMANCHE	FREDERICKSBURG		WALNUT	
CRETACEOUS	COMANCHE	TRINITY		PALUXY	
CRETACEOUS	COMANCHE	TRINITY		UPPER GLEN ROSE MEMBER	
CRETACEOUS	COMANCHE	TRINITY		GLEN ROSE ANHYDRITE MEMBER	
CRETACEOUS	COMANCHE	TRINITY		LOWER GLEN ROSE MEMBER	
CRETACEOUS	COMANCHE	TRINITY		UN-NAMED SANDSTONE AND SHALE	
CRETACEOUS	COMANCHE	TRINITY		UN-NAMED MARINE LIMESTONE AND SHALE	
CRETACEOUS	COMANCHE	TRINITY		UN-NAMED BASAL CRETACEOUS	

Lithologic Character



Geologic Notes

Fayette formation.—Marine and brackish water, near shore and continental accumulation of light-colored sandy clay, sand, and green ashy clay. An important oil-producing horizon especially in southern part of Texas.

Yegua formation.—Heterogeneous accumulation of sand, clay, lignite, sandy clay, carbonaceous clay lentils, and concretion. Clays range in color from light greenish gray to dark brown. An important oil-producing horizon in coastal part of Texas and carries showings of oil and gas in Urania field, Louisiana.

Crockett formation.—Grayish-brown clay shale; greenish glauconitic fossiliferous shale and marl; ferruginous cross-bedded sandstone, brown or gray, generally containing lumps of clay and glauconite; limestone lentils chiefly in upper and lower parts of formation.

Sparta formation.—Soft sandstones and light-colored clays. In the central part of the East Texas embayment there is a thin sandy glauconite zone—the Tyler greensand—which is used for surface mapping. Formation contains oil and gas shows in Urania field, Louisiana.

Weches formation.—Predominantly a reasonably pure fossiliferous clayey glauconite carrying siderite concretions and cross-bedded sands in some places. Iron ore occurs irregularly throughout the formation. Unweathered beds are bluish green but on exposure turn to a deep reddish brown. The Weches is an important horizon for surface and subsurface mapping. Contains oil in Chireno field, Nacogdoches County, and may develop into a prominent producing horizon in the Gulf Coastal part of Texas.

Queen City formation.—Fairly thick beds of clean cross-bedded light-colored sandstone; clay and sandy clay; thin beds of lignite and bentonitic clays occur chiefly in the upper half of the formation. About the middle is a thin fairly persistent greensand horizon which has been called the Omen greensand and is an important horizon for mapping. Cane River correlative of Queen City has showings of oil and gas in Urania field in Louisiana.

Reklaw formation.—Fossiliferous glauconites, glauconitic clays, brown and blue micaceous sandy clay with glauconite stringers and clay ironstone concretions. Weathers to a reddish color. Is an excellent horizon for surface and subsurface mapping.

Carrizo formation.—Medium-grained sandstone with a small amount of sandy clay. Breaks down in many places into loose white sand. In localities ferruginous material colors outcrop. Rests unconformably on older formations. Carries oil in commercial quantity in the Kittrell field in the southern part of Houston County and showings of oil south of Slocum in Anderson County.

Wilcox group.—The Wilcox group is a heterogeneous accumulation of sandy clays and shales, cross-bedded soft micaceous ferruginous sandstones, large hard sandstone boulders, lignitic shale, and beds of lignite. Lithologically the Wilcox has been divided into three formations—the Seguin at the base, the Rockdale in the middle, and the Sabinetown at the top. Locally the Sabinetown has thicker sandstone beds and more marine fossiliferous shales than the other two formations; the Rockdale more lignitic shale and beds of fair quality lignite; the Seguin contains more clay than the remainder of the Wilcox and more local oyster-bearing calcareous silts or sandy limestones. It is a difficult group to subdivide either at the surface or in subsurface work. Produces oil in Urania field, Louisiana.

Midway group.—The Midway has been subdivided into several local members. From base to top in East Texas they are Littig, Pisgah or Tehuacana, and Wills Point. The Littig and Pisgah are called by some the Kincaid formation. Glauconitic fossiliferous sandstone and greensand comprise the Littig or basal member of the Midway. Overlying it are oyster-reef lenticular nodular calcitic glauconitic limestones usually referred to as Tehuacana or Pisgah limestones. Over the fossiliferous limestone lentils of middle Midway age are fossiliferous clays, glauconitic sands, concretionary beds with limestone lentils bearing aragonite and siderite which grade upward into dark gray silty or sandy clay. The basal members of the Midway are good horizons for surface mapping and are also readily identified in the subsurface. Core drilling along the Mexia-Powell fault zone and on Van structure has utilized these Midway beds for structural control. In the Van field the sandy parts of the Midway locally carry oil—probably saturated from below.

Navarro group.—The Navarro of northeastern Texas is variable in thickness and character. In the middle of the group there is a fairly persistent silty sand section usually referred to as the Nacatoch formation. Below the Nacatoch are marls, shales, and sandy shales carrying zones of concretions which have been called Neylandville formation. Above the Nacatoch is the Kemp formation composed of clays and sandy clays carrying concretions. In Texas and Louisiana the Nacatoch carries oil and gas.

Taylor group.—The Taylor group in the East Texas embayment includes a variety of lithologically variable fossiliferous formations composed of chalk, marly shale, sandy shale, and sand. The two prominent and most persistent chalk zones of the Taylor—the Gober in the basal part and the Pecan Gap in the upper part—are fairly reliable horizons for subsurface structural mapping. The Wolfe City is locally known as the "Corsicana" sand and has produced considerable oil and gas around Corsicana, Navarro County, Texas. The Brownstown is considered by some to be uppermost Austin in age. In Van oil field the Pecan Gap chalk, where shattered along fault zones, is thoroughly saturated with oil and gas.

Austin group.—In the western and southern parts of the East Texas embayment the Austin group is composed of fossiliferous white chalky limestone, limy marl, shell marl, and thin beds of grayish shale. Over this area the aggregate thickness varies between 400 and 800 feet—the group having its maximum in the northwestern part of East Texas. In the northeastern part of East Texas the Austin group splits from base to top into Ector chalk, Bonham clay, Blossom sand. The Ector chalk formation retains the chalky phase of the Austin; the Bonham clay overlies the Ector and is a greenish-gray waxy clay reaching a thickness of 600 feet and is especially well developed along Red River in northeastern Texas and southeastern Oklahoma; the top member or Blossom sand varies in character from west to east along Red River from calcareous clay to brown sandy ferruginous glauconite beds intercalated with thin clay layers. In northern Louisiana the sandy phase is fairly well developed. In this region it is an important oil-producing horizon. In the Van field the Austin chalk, where shattered along fault zones and planes, is highly saturated with oil and gas.

Eagle Ford group.—A dark gray to black fossiliferous shale, locally sandy in places and containing thin hard sandstones in basal part. Sandy material in places glauconitic and lignitic. Near the top of the group in localities there is a fairly well developed silty sand zone which is called sub-Clarksville. In some wells in the Camp Hill field in Anderson County and in the Van field in Van Zandt County the sub-Clarksville produces oil and gas commercially. In D. B. Holley No. 1, 5 miles southwest of Winnsboro in Wood County, good oil showings were found in this horizon. Over the northern and western parts of the East Texas embayment the Eagle Ford is readily separable from the Woodbine, but in the southern part where the Woodbine is similar to the Eagle Ford in character and where it carries marine fossils the distinction is difficult. In southeastern Oklahoma, northeastern Texas, southwestern Arkansas, and northwestern Louisiana the Bingen represents both groups. A maximum normal thickness of Eagle Ford in the East Texas embayment is about 500 feet, though in many localities it is much thinner because of truncation on structure.

Woodbine group.—The southernmost surface exposure of the Woodbine sand is in the northern part of McLennan County, where the group has thinned to practically nothing. From this locality it crops out on the west flank of the East Texas embayment northward through Hill, Johnson, Tarrant, Denton, and Cooke counties, Texas. In the northeastern part of Cooke County it swings east around the Preston anticline, thence across the north end of Grayson County, Texas, thence northward into Bryan County, Oklahoma, and through Choctaw and McCurtin counties, Oklahoma and Arkansas. From its outcrop the Woodbine dips east and south into the East Texas embayment. Southward from the latitude of the central part of Henderson County the sand content of the Woodbine becomes less and the marine shale content increases until it cannot be separated with assurance from Eagle Ford. On the east side of the East Texas embayment the Woodbine is truncated against the west flank of the Sabine uplift, approximately along the east edge of the East Texas oil field, and thence northeastward to the northeast corner of Camp County. Subdivision of the Woodbine on the surface and in the subsurface is difficult except locally. On Van structure the upper half is decidedly bentonitic, whereas the lower half carries only a small amount of bentonite. Red, blue, and gray mottled shales are found throughout the group, though more frequently in the middle third. From northeast toward the southwest and south in the embayment the amount of bentonite decreases. Along the axis of the basin the thickness of the Woodbine remains fairly constant, 700 to 800 feet, though the sand content decreases as the shale increases toward the south. The presence of dark gray and black fossiliferous shale in the Woodbine section in Anderson and Leon counties and the difficulty in separating the Woodbine from the overlying Eagle Ford suggest that in this area they represent continuous deposition. Main oil and gas-producing horizon in the East Texas embayment; also an important oil and gas-producing horizon in Louisiana.

Washita group.—The Washita group, usually referred to as the Georgetown limestone in the subsurface under the East Texas embayment, is seldom subdivided because of its lithologic unity. Generally the Washita and Fredericksburg are considered as a single limestone group about 1,100 feet thick representing all Lower Cretaceous beds above the Paluxy where present and above the Glen Rose where the Paluxy is not present. At surface outcrops the Washita is readily divisible into definite formations. At Kelsey 25 to 50 feet of hard brownish-gray shale of the top part of the Washita seems to grade upward into Woodbine without evidence of unconformity. At Van fossiliferous copper-colored Lower Cretaceous shales averaging about 15 feet thick overlie gray Comanche limestone. Between the copper-colored shales and the Woodbine is a variable thickness (4 to 15 feet) of gray shale or gray sandy shale, carrying re-worked Comanche Foraminifera where the shales are not sandy. It appears to be a transition zone between the Lower and Upper Cretaceous. At the south end of the East Texas field the gray Comanche limestone is overlain by fossiliferous copper-colored Comanche shales which in turn are overlain by gray shales and gray sandy shales that grade upward into unquestionable Woodbine. Here also there are re-worked Comanche Foraminifera in the gray shales where they are not sandy. The Georgetown has had showings of oil and gas in a few wells and in one well produced several thousand barrels of oil from a fractured zone along a minor fault on Kosse structure, Limestone County, Texas.

Fredericksburg group.—In the subsurface of the East Texas embayment the Fredericksburg is usually not differentiated from the overlying Washita—the two groups aggregating about 1,100 feet of section, predominantly hard gray limestone. The Fredericksburg contains more dark gray and black shale and limestone. There is no difficulty in recognizing the usual formations of the Fredericksburg at their surface outcrop.

Paluxy formation.—A sandstone and shale member at top of Trinity, which cannot be readily separated on surface from remainder of underlying Trinity north of latitude of Decatur, Wise County, Texas, where Glen Rose limestone of middle Trinity pinches out, leaving Paluxy resting directly on sandstones and shales of lower Trinity. Surface outcrop swings around west and north flank of East Texas embayment from its southern surface limit in Somervell County, northward through Hood, Parker, Wise, Montague, Cooke counties, Texas, and eastward through Love, Carter, Marshall, Johnston, Atoka, Choctaw, Pushmataha, McCurtin counties, Oklahoma and Arkansas. Pinches out in subsurface against west flank of Sabine uplift on east side of East Texas embayment. Southern subsurface limit not known in detail but drilling shows it is not present in Mexia field, Limestone County; North Currie and Powell fields, Navarro County; Cayuga field, Anderson County; and in the southern parts of Rusk and Panola counties. It undoubtedly flanks the north side of the Sabine uplift but loses its identity in the rest of the Trinity group in Louisiana. At Kelsey dome in Upshur County it was encountered between 4,955 and 5,310 feet and is composed of hard gray and white fine silty sand, lignitic in places; gray sandy shale; and red silty shale. In Davis 6-T-1 at Van dome in Van Zandt County it was encountered between 4,739 and 4,946 feet and is composed of hard gray and brown fine shaly sand; hard, dark gray, sandy shale; and an occasional thin hard gray sandy limestone. In Gardner Bros. et al. Leonard No. 1 on the northwest flank of the Van dome 272 feet of Paluxy were found. No red shale was noted at Van though the entire Paluxy section was cored and recovery was good. A comparison of the thicknesses of the Paluxy at Kelsey and at Van confirms surface evidence of the wedging out of the sandstone southward toward the mouth of the East Texas embayment.

Upper Glen Rose member.—In Van field, Van Zandt County, there are about 500 feet of hard gray limestone and dark shale below the Paluxy and above the anhydrite zone of the middle part of the Glen Rose. In Kelsey dome the main anhydrite zone has not been reached, only a thin streak of anhydrite being reported at 5,970 feet. The Glen Rose penetrated is composed of hard gray limestone, dark shales, some thin gray sandstone and a small amount of red shale. At Bellevue field in the Louisiana embayment there is a 600 foot normal upper Glen Rose section above the anhydrite zone. At Homer, Louisiana, it is 850 feet; at Cotton Valley 460 feet; at Pine Island, Louisiana, probably about 600 feet where not cut out by local unconformity on structure. On Kelsey dome, the Glen Rose was penetrated to a depth of 850 feet, and doubtless at that depth the test was near the anhydrite section. At Mexia, Powell, and Ennis practically no anhydrite is found in the Glen Rose. In Gulf Production Company Carraway No. 1 in Shelby County, Texas, Glen Rose anhydrite appears to have been found between 4,665 and 4,810 feet, considerably deeper in the Trinity section than it occurs to the north. Has had showings of oil in North Currie, Mexia, and Kosse, Texas.

Glen Rose anhydrite member.—The Glen Rose anhydrite section of the East Texas and central Louisiana embayments is represented in places at the Glen Rose outcrop by thin layers of gypsum and celestite. At Van there is a definite anhydrite section between 5,461 and 5,826 and a few beds within the next few hundred feet. With the anhydrite, which is very dense and hard, are interbedded gray hard limestone and dark shales. The Glen Rose anhydrite zone at Van is 365 feet thick; at Pine Island 450 feet thick; at Bellevue, Cotton Valley, and Homer 500 feet; in Bethany gas field, Panola County, Texas, about 550 feet. In the southern part of Shelby County, 145 feet of Glen Rose anhydrite section is recorded in Gulf Production Company Carraway No. 1, though if better samples were available the section might be found to be thicker. The zone in East Texas and central Louisiana is not well defined as stringers are found above and below the main zone. Has produced one small oil well in Pine Island, and gas in Cotton Valley, Louisiana.

Lower Glen Rose member.—The lower Glen Rose section at Van contains 659 feet of hard gray limestone, gray and black shale, an occasional streak of anhydrite and red shale, some fine silty hard sandstone. Miliolids, oolites, and comminuted shell fragments give local porosity. At Pine Island there are 900 feet of material similar to that at Van, at Homer 1,000 feet, and at Bellevue and Cotton Valley about 1,100 feet. At Kosse and Mexia in Limestone County and at North Currie and Powell in Navarro County the anhydrite is not present in a sufficient amount to separate the lower Glen Rose limestone from the upper Glen Rose limestone and therefore no accurate measurements can be made by the lower Glen Rose limestone section. This horizon produces oil and gas in commercial quantity in Pine Island, Rodessa, Cotton Valley, and Bellevue, Louisiana; had commercial production in one well in Mexia, Texas; and has had showings in North Currie and in a flank well at Van, Texas. In Rodessa production comes from sandy zones in the oolitic limestone 150 to 200 feet below the base of the anhydrite zone.

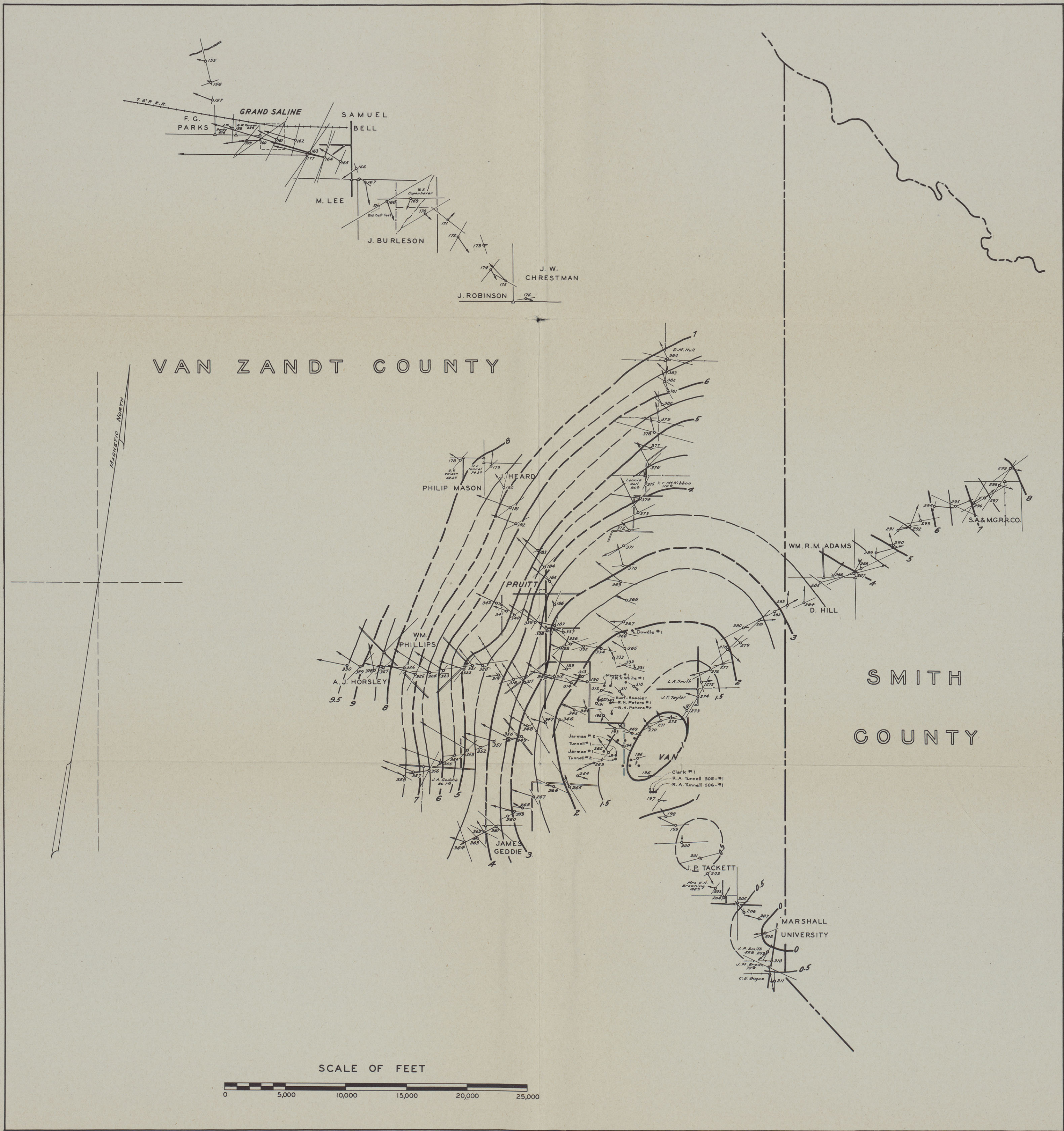
Un-named sandstone and shale unit.—A sandstone and red shale section which may be the upper part of the Trinity or Antlers sandstone section at their marginal exposures, or which may be the basal Trinity in shoreward areas where underlying Cretaceous may not have been deposited, lies below the Glen Rose limestone and anhydrite section in much of the central part of the basinal areas of East Texas and central Louisiana. Until drilled through in Pine Island and Bellevue the thick sandstone and red shale section below the Glen Rose was thought to be the basal Cretaceous. Now it is known that there is a marine fossiliferous clay and limestone section below about 2,000 feet of sandstone and red shale. The exact age of the marine beds is not known but fossils in them suggest Lower Cretaceous. At Van a very similar nonmarine section below the Glen Rose limestone and anhydrite section was penetrated 1,000 feet, and at Cotton Valley 1,390 feet. There is doubtless another 1,000 feet of similar material at Van above the marine beds. Showings of oil and gas have been encountered in this section in Bellevue; production from the upper part of it—"Herndon" oil sand in Pine Island; stained in places by oil in Cotton Valley.

Un-named marine limestone and shale unit.—Dark gray brittle slightly calcareous shale; hard dark fossiliferous clayey and sandy limestone in Bellevue and in Pine Island. Probably underlies Van and area to the southeast. Has not been recognized and probably does not exist in shoreward phase of Trinity or at its outcrop. Section has been penetrated 175± feet at Pine Island; 330 feet at Bellevue; and 426 feet at Cotton Valley. 192,000 cubic feet of gas and showing high gravity oil between 6,119–6,125 feet, or 194 feet below top of lower Trinity marine Cretaceous, have been found in one well in the Cotton Valley field.

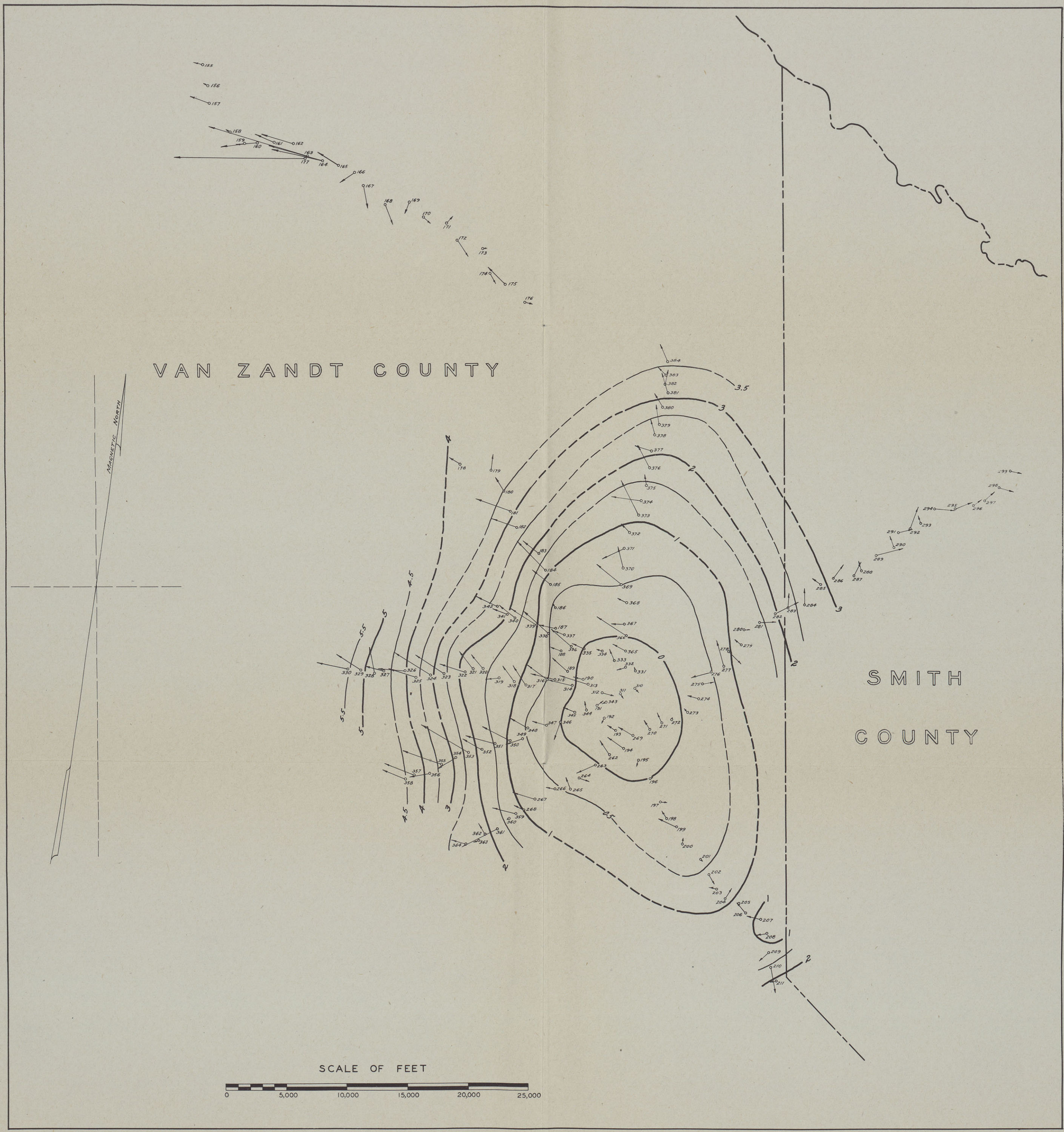
Un-named basal Cretaceous unit.—May be basal part of Lower Cretaceous sandstone and shale section lying between Glen Rose formation and pre-Cretaceous schists in Luling field, Caldwell County, Texas. If so the marine beds which separate this sandstone and shale deposit from the similar section which lies directly below the Glen Rose in northern part of Louisiana are not present. No wells along the Mexia-Powell line of faulting, or in East Texas, have been drilled deep enough to reach this horizon.

STRATIGRAPHIC SUCCESSION OF CRETACEOUS AND EOCENE BEDS IN THE EAST TEXAS EMBAYMENT. NOT DRAWN TO SCALE. ONLY MAJOR UNCONFORMITIES INDICATED.

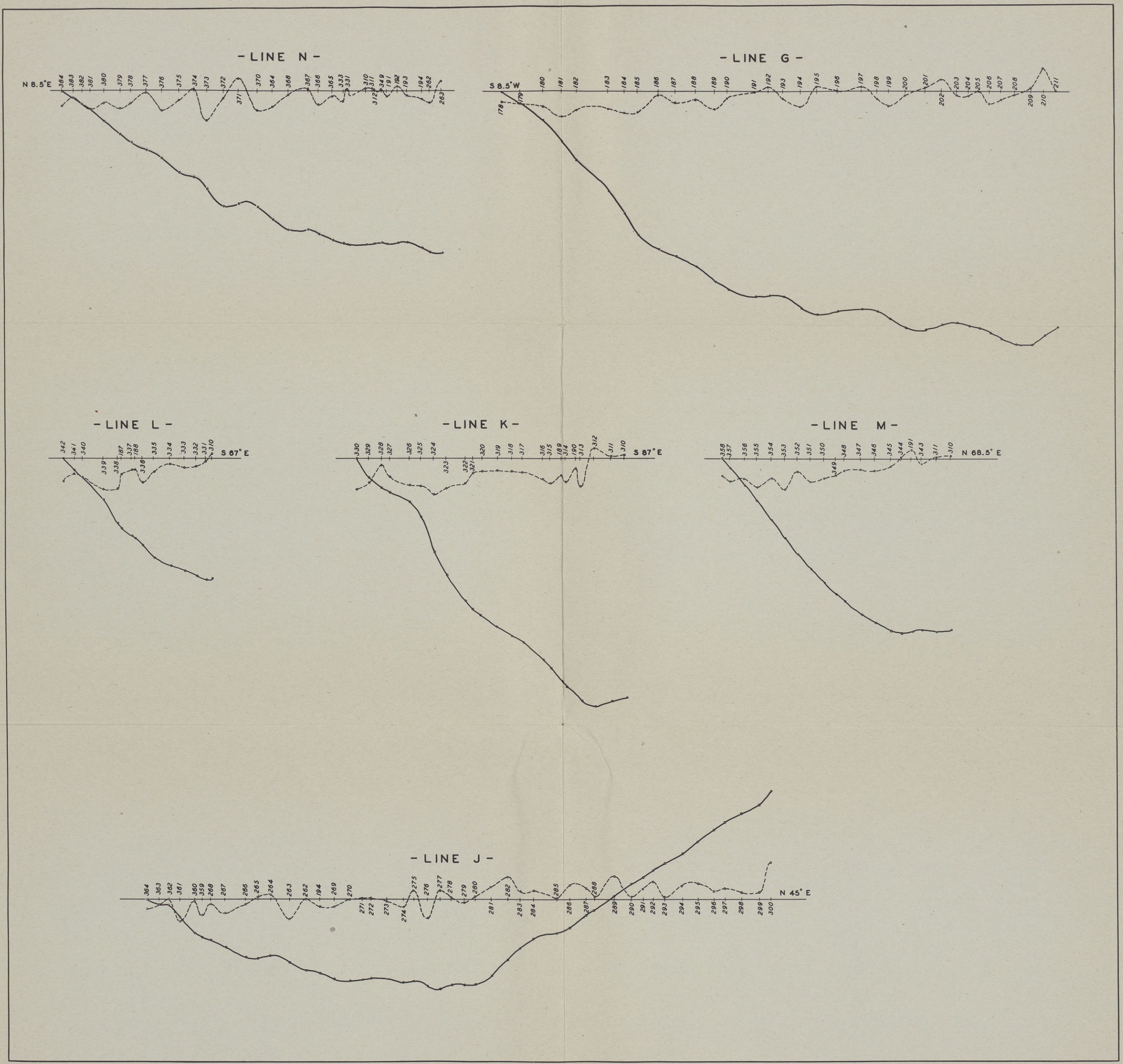
Refraction seismograph survey of the Van area indicating the outline of the Van uplift as determined by refraction reconnaissance survey. F. P. indicates firing points. Numbered lines radiating from firing points indicate location of recording stations.



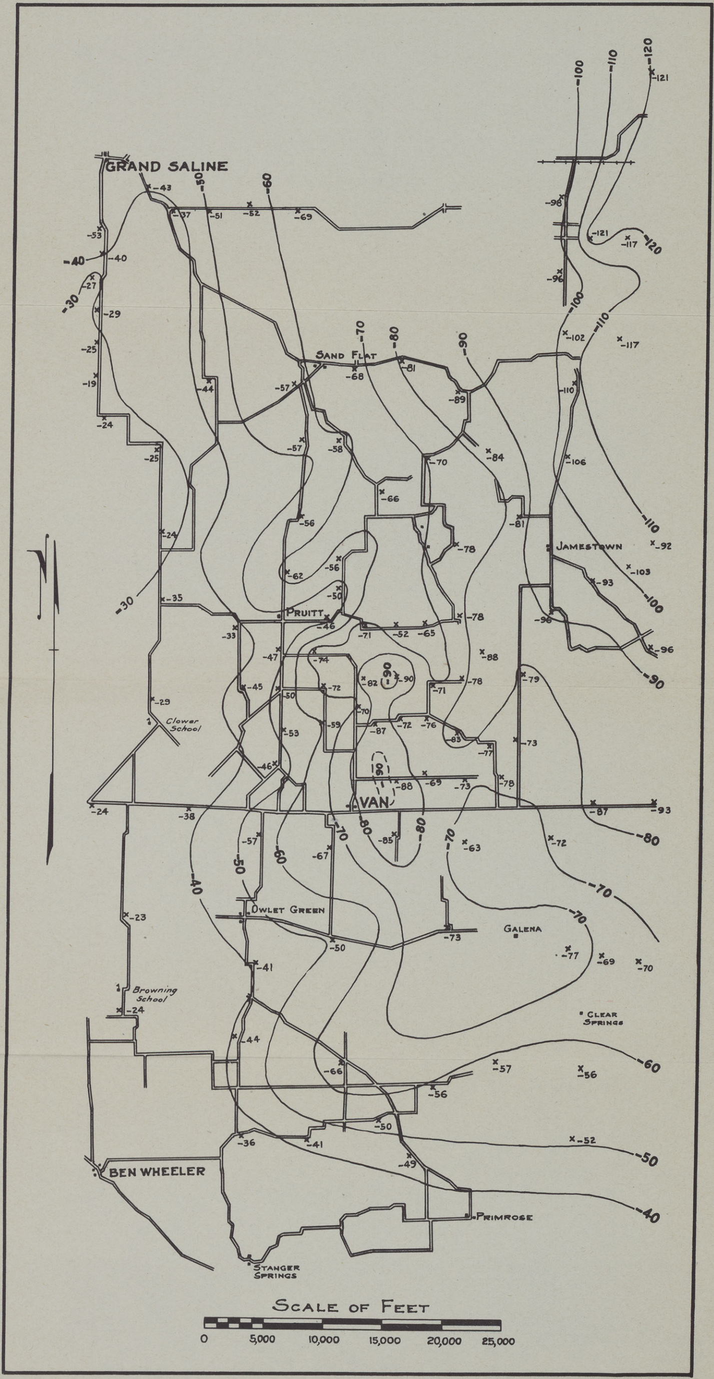
Torsion balance reconnaissance survey of the Grand Saline-Van area in Van Zandt and Smith counties. Isogams calculated from observed gradient values without subtraction of regional gravity effect. Scale of gravitational anomalies is 1 mm. = $2x10^{-9}$ C.G.S. Isogam interval is $0.5x10^{-9}$ C.G.S. Survey made by Torsion Balance Exploration Company.



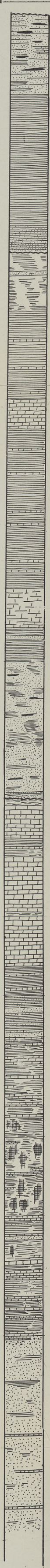
Torsion balance reconnaissance survey of the Grand Saline-Van area in Van Zandt and Smith counties. Isogams calculated from observed gradient values with subtraction of regional gravity effect giving regionally corrected isogams. Scale of gradients is 1 mm. = 2x10⁻⁹ C.G.S. Isogam interval is 0.5x10⁻⁹ C.G.S. Regional gradient is Vxz = +2.8 E.; Vyz = −2.8 E. Survey made by Torsion Balance Exploration Company.



Torsion balance gravity curves accompanying the torsion balance reconnaissance survey of the Grand Saline-Van area in Van Zandt and Smith counties. Numbers indicate station locations on survey as shown by Plates 5 and 6. Gradient curves shown by broken lines on scale of 1 mm. = 1 E. Delta gamma curves shown by solid lines on scale of 1 mm. = 0.5×10^{-4} C.G.S.

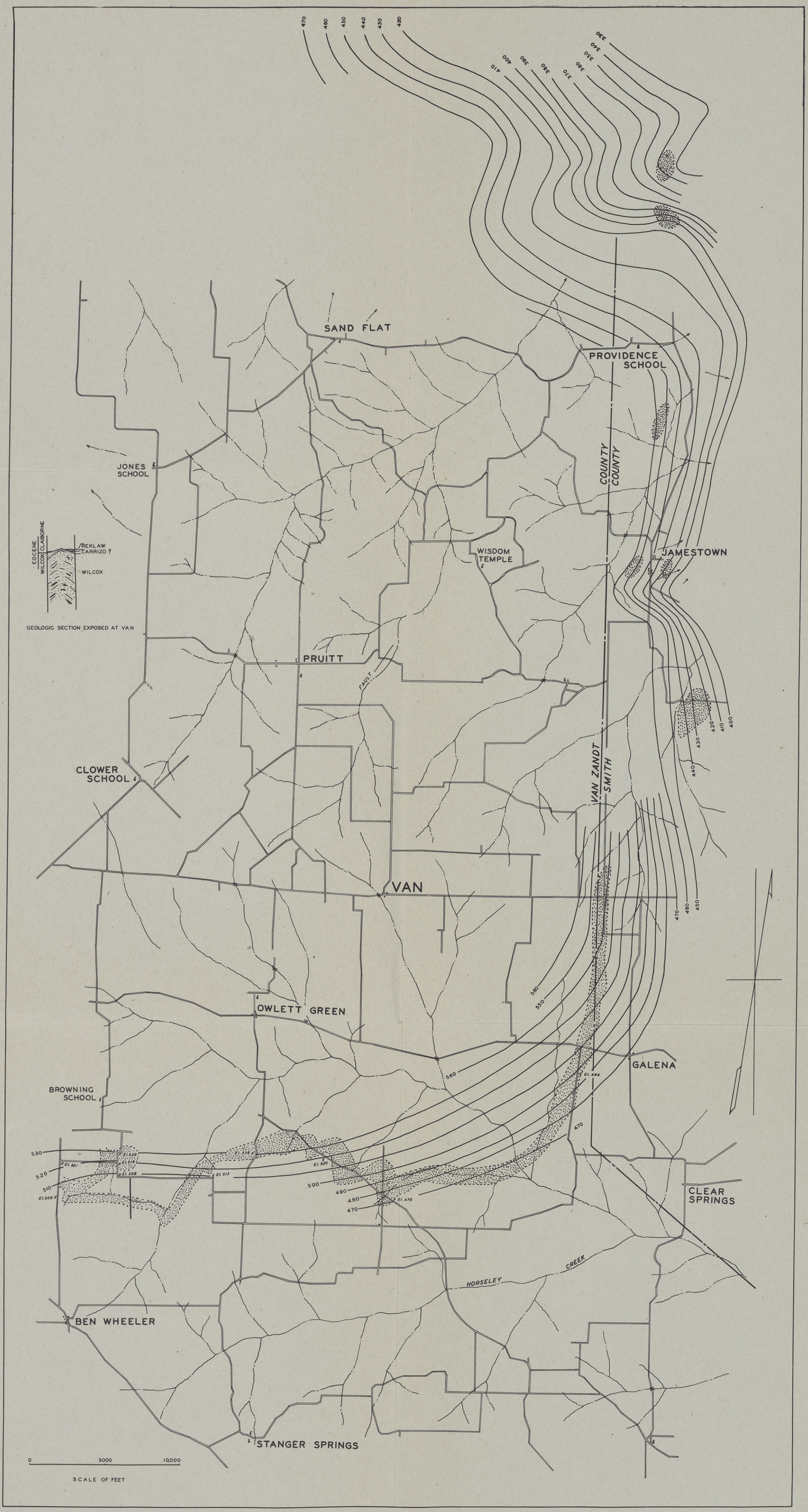


Magnetometer survey of the Van area, Van Zandt County. Contour interval 10 gammas.

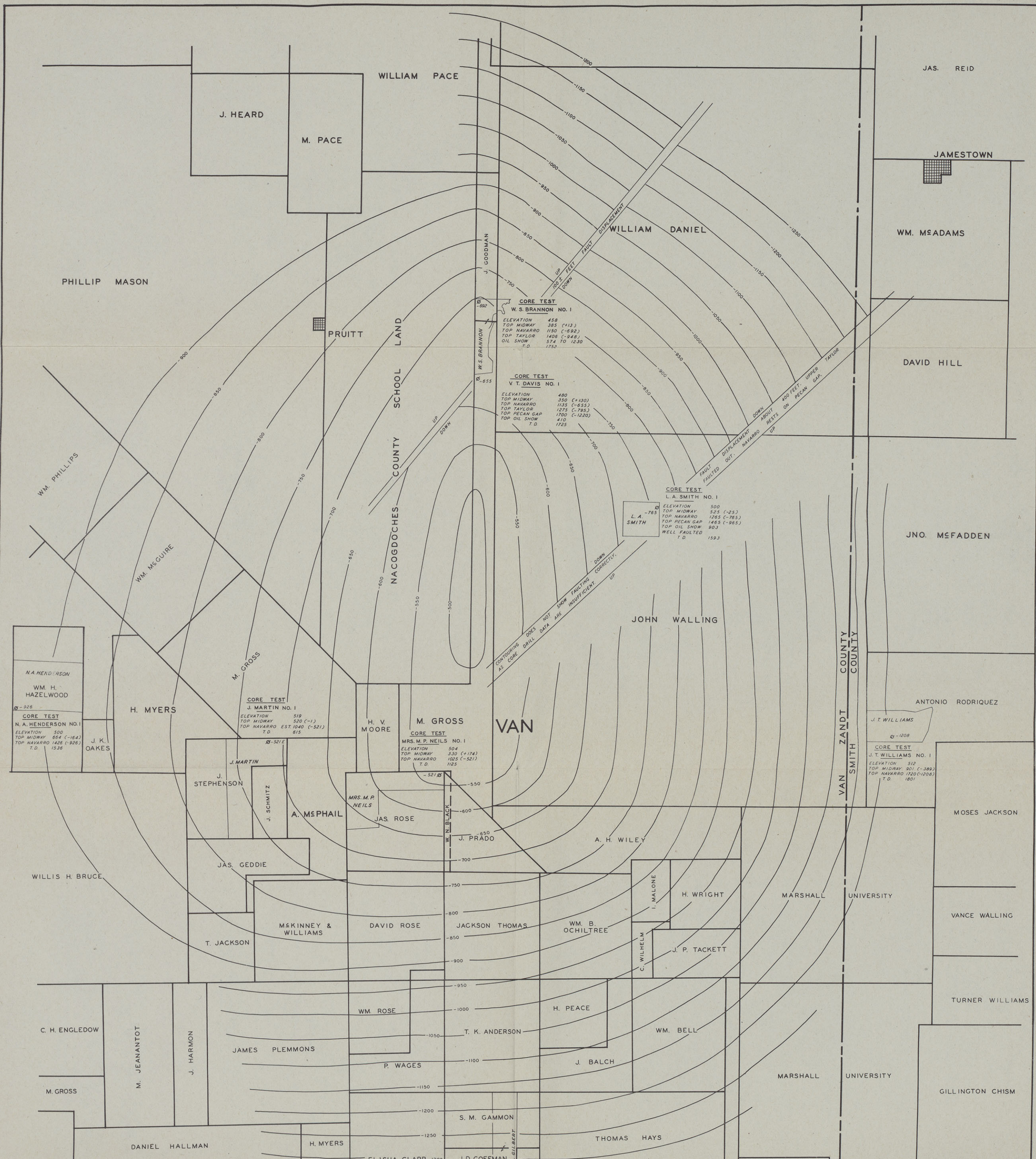


System	Series	Group	Formation	Geologic Notes
TERTIARY	EOCENE	WILCOX	Undifferentiated	*Wilcox group.*—Only the basal part of the Wilcox is present on the top of the Van dome, the upper part having been removed by erosion. It is composed of fine loosely cemented gray and brown micaceous lignitic sandstone; gray sandy lignitic shale locally calcitic; shaly silty sandstone containing silicified wood and limonite pebbles; irregularly developed impure lignite beds; slightly saturated in places along faulting. Average unfaulted thickness on apex of Van dome is 300 feet; thickens off structure to about 1,100 feet.
		MIDWAY	Undifferentiated	*Midway group.*—Gray fossiliferous silty shale; locally carries a little bentonite, calcite, mica, and finely disseminated lignite and pyrite. The basal part contains more silty sand and glauconite than the remainder of the Midway. Along fault zones on Van structure the sandy material, especially in the basal part of the group, is saturated with oil and gas. The thickness of the Midway on the Van uplift is approximately 650 feet, and this seems to be 150 feet thinner than the average for the surrounding territory.
CRETACEOUS	GULF	NAVARRO	KEMP NACATOCH NEYLANDVILLE	*Navarro group.*—The Navarro at Van is composed of fossiliferous gray sandy shale, calcareous in places, containing glauconite, pyrite, and thin laminae of sandstone. Along fault zones the sandstone carries oil. Normal off-structure thickness of Navarro in Van area 300 feet; over Van dome thins about 50 feet. Slightly above the middle of the group is a fairly well developed sandy member called the Nacatoch sand. It is made up of medium-hard gray calcareous shaly glauconitic sandstone containing a little mica. Saturated with oil and gas, especially along faulting on Van structure.
		TAYLOR	UPPER TAYLOR	*Upper Taylor formation.*—Fossiliferous gray shale and gray sandy shale with occasional chalky shales and lenses of chalk. Shales locally pyritic and glauconitic. The upper Taylor does not thin appreciably over the Van structure.
			PECAN GAP	*Pecan Gap formation.*—Grayish-white moderately hard uniform chalk. Shows little thinning over Van uplift. In shattered zones along faulting the chalk is highly saturated with oil and gas and is stained brown.
			LOWER TAYLOR FORMATIONS	*Lower Taylor formations.*—Fairly uniform fossiliferous deposition composed of gray shale, gray sandy shale, and chalky shale carrying thin lenses of light-colored limestone. The lower Taylor on top of the Van structure is about 100 feet thinner than it is in the area surrounding the uplift.
		AUSTIN	Undifferentiated	*Austin group.*—The Austin is a characteristically gray marly soft chalk thinning from 315 feet off structure to 200 feet on top of the Van structure where not faulted. Along fault zones where shattered the Austin is highly saturated with oil and gas, is dark brown in color, and is capable of commercial production under these conditions.
		EAGLE FORD	SUB-CLARKSVILLE	*Eagle Ford group.*—Off structure at Van the Eagle Ford is approximately 425 feet thick, and where not affected by faulting it thins gradually to 175 feet on the top of the Van structure. It is composed of dark gray to black well-bedded micaceous shale. Around the flanks of the Van dome there is in the upper part of the Eagle Ford a silty sand varying from zero to 30 feet thick. This sand is called the sub-Clarksville. Where developed above water level on the Van uplift, it carries oil and gas in commercial quantity. In the basal part of the Eagle Ford there is a considerable amount of volcanic ash and waxy clay which gives the shale a "speckled" appearance.
		WOODBINE	BENTONITIC PART NON-BENTONITIC PART	*Woodbine group.*—The Woodbine group at Van has a normal thickness of 700 feet part-way down the flank of the Van structure, but there is a suggestion that there is an additional 100 feet in areas adjacent to but not influenced by the uplift. On the present highest point of the structure a maximum thickness of Woodbine seems to be not over 650 feet, though slight faulting may cut out 50 feet of Woodbine section without being detected. Lithologically the Woodbine in the field is made up of bentonitic or ashy bluish-gray sand; mottled red, white, blue-gray bentonitic shale; clean brown fairly soft porous sandstone; and in the basal 150 feet some lime-cemented fairly hard sandstone with less than the average porosity of other sandstone in the formation. In the upper half of the Woodbine the sandstones are quite bentonitic or ashy, though there are beds of clean non-bentonitic sandstone; whereas in the lower half, the clean non-bentonitic sandstone comprises the major part of the formation, there being only an occasional bentonitic sandstone. Mottled or gray shales occur in irregular shaped masses or lenses throughout the Woodbine, but show a slight concentration in the middle third. Individual beds of shale or sandstone cannot be correlated with certainty, even between off-set wells; thick beds of shale or sandstone finger into each other within a few feet. Porosity in the sandstone ranges from 8 to 33 per cent. Throughout the Van field the Woodbine averages 50 per cent sand and 50 per cent shale. All sandstones above the water level are saturated with oil or gas; considerable lignite is scattered through the sandstones of the Woodbine, and there are erratic thin layers of conglomeratic material. Main producing horizon in Van field.
	COMANCHE	WASHITA AND FREDERICKSBURG	Undifferentiated	*Washita and Fredericksburg groups.*—The Washita and Fredericksburg have not been subdivided in the Van field. They total 1,100 feet of hard gray limestone with which is interbedded a lesser amount of dark gray and black shale. The proportions average 80 per cent limestone and 20 per cent shale, the shale occurring in three zones—the first about 50 feet thick and lying 200 feet below the top of the Comanche; the second about 25 feet thick and lying in the middle of the Washita-Fredericksburg section; the third comprising the basal 125 feet of the Washita-Fredericksburg, immediately overlying the Paluxy. The limestone is uniformly hard and dense, but in places is fossiliferous. At the top of the Comanche are copper-colored fossiliferous shales from 5 to 30 feet thick which grade up into gray sandy shales averaging about 10 feet thick. These in turn grade into basal Woodbine without noticeable lithologic break. There seems to be no thinning of the Fredericksburg and Washita over the Van uplift.
		TRINITY	PALUXY	*Paluxy formation.*—Firm fine beds of sandstone varying from 1 inch to 20 feet in thickness; hard sandy shale; an occasional thin hard bed of gray limestone. The sandstone has good porosity and makes up about 40 per cent of the formation. Oil-stained sandstone was cored at three levels in the Paluxy in V. T. Davis 6-T-1, though this well is structurally 1,000 feet below the highest point on the Van dome. Davis 6-T-1 had 207 feet of Paluxy formation whereas Gardner Bros. et al. Leonard No. 1, 3 miles northwest of Davis 6-T-1 and farther down the flank of the dome, had 272 feet of Paluxy.
			UPPER GLEN ROSE MEMBER	*Upper Glen Rose member.*—Alternating hard gray limestone and dark gray to black shale in about equal proportions. In the upper 100 feet of the zone are some thin streaks of fine hard sand and in the basal 50 feet is a little anhydrite.
			GLEN ROSE ANHYDRITE MEMBER	*Glen Rose anhydrite member.*—Predominantly hard dense gray anhydrite with a lesser amount of hard gray limestone and dark gray to black shale. The main anhydrite zone of the Glen Rose.
			LOWER GLEN ROSE MEMBER	*Lower Glen Rose member.*—Gray, black, and tan-colored limestone locally sandy alternating with black and dark gray shale; some fine fairly hard sandstone, especially in the upper part of the formation; a small amount of red shale and anhydrite. Two hundred feet above the base of the formation an oil showing was encountered in V. T. Davis 6-T-1 in sandy limestone mainly composed of comminuted shell fragments.
			UN-NAMED SANDSTONE AND SHALE	*Un-named sandstone and shale formation.*—Fine-grained gray to white and red sandstone, lime-cemented in places and shaly in other places; blue, gray, and red shale, locally sandy; a little gray limestone. Some lignite and gravel inclusions in top conglomeratic part of formation. Beds are firm enough to stand up well in drilling. The 1,000 feet of this formation which have been penetrated average about 80 per cent sandstone; the remaining 20 per cent is shale.

GEOLOGIC SECTION PENETRATED BY DRILLING IN THE VAN FIELD, VAN ZANDT COUNTY. GRAPHIC SCALE: 1 INCH EQUALS 400 FEET.



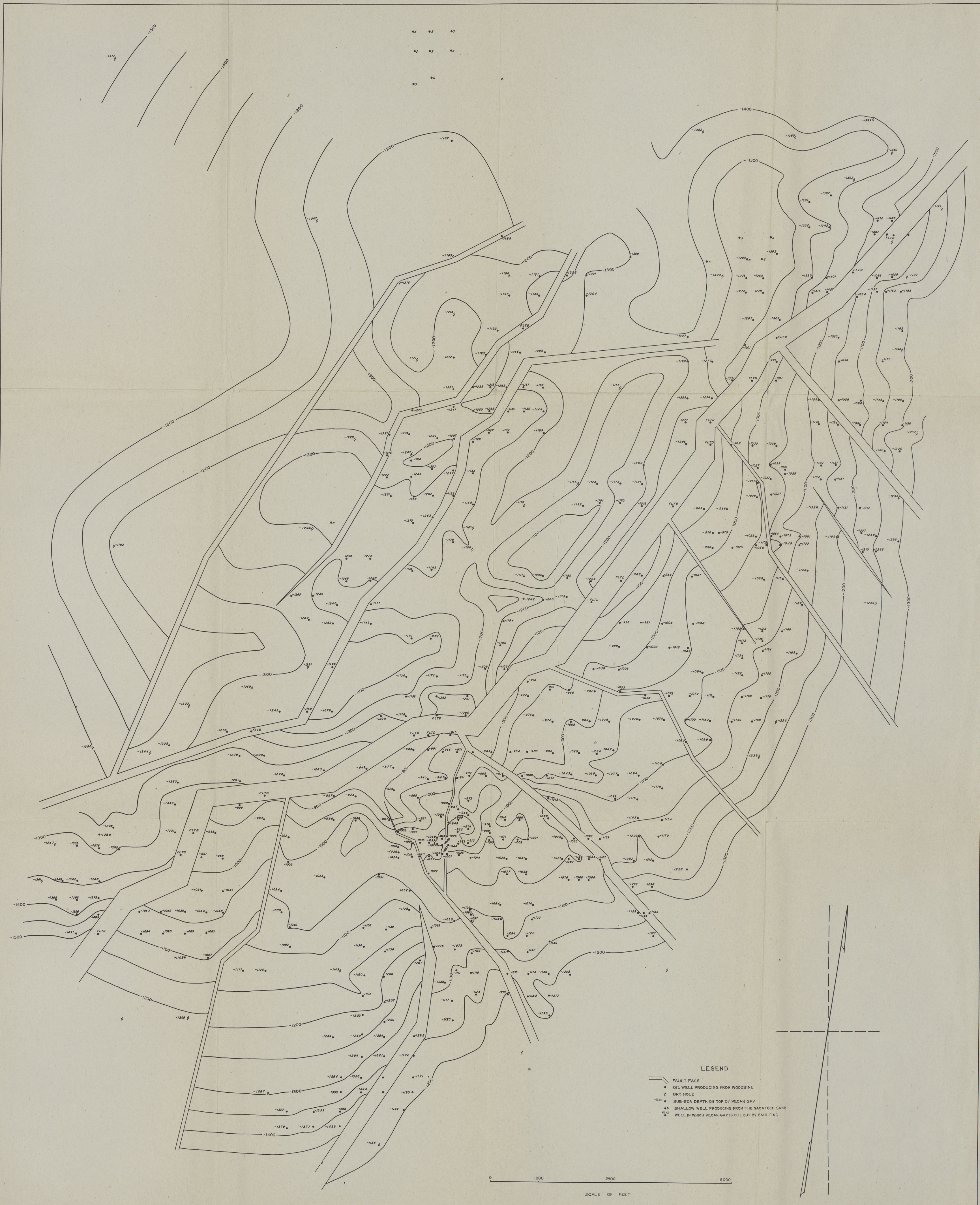
Map showing areal geology, surface structure, and drainage of the Van area, Van Zandt and Smith counties. Contoured on top of Reklaw green sand, sea level datum. Reklaw outcrop shown by stippling. North and west of Reklaw outcrop the surface formation is Wilcox; south and east, it is Queen City. Mapping by G. A. Weaver, John Doering, F. E. Poulsen, and Arthur Wedel.



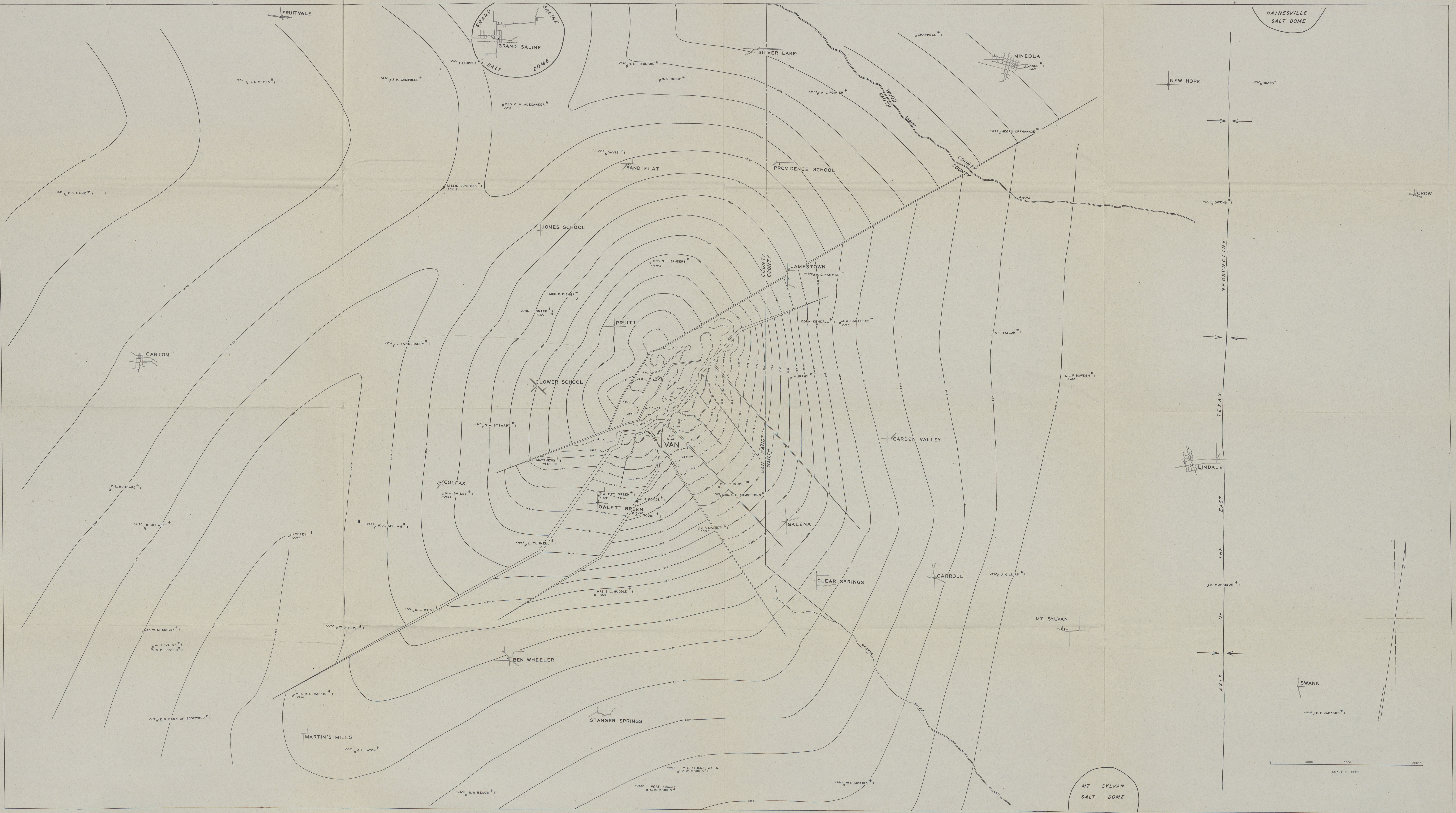
Copy of original subsurface structure map of Van uplift made in 1929 from core drill data. Contour interval 50 feet. Original map contoured with 20-foot intervals. Contoured on top of the Navarro formation. Datum sea level. Est. indicates estimated value.

Structural map of the Van uplift contoured on top of the Midway formation. Contour interval 50 feet. Datum sea level. Wells in fault faces carrying no contour value have Midway faulted out. Wells not in fault faces and carrying no contour value are indeterminate.

Structural map of the Van uplift contoured on top of the Navarro formation. Contour interval 50 feet. Datum sea level. Wells in fault faces carrying no contour values have Navarro faulted out

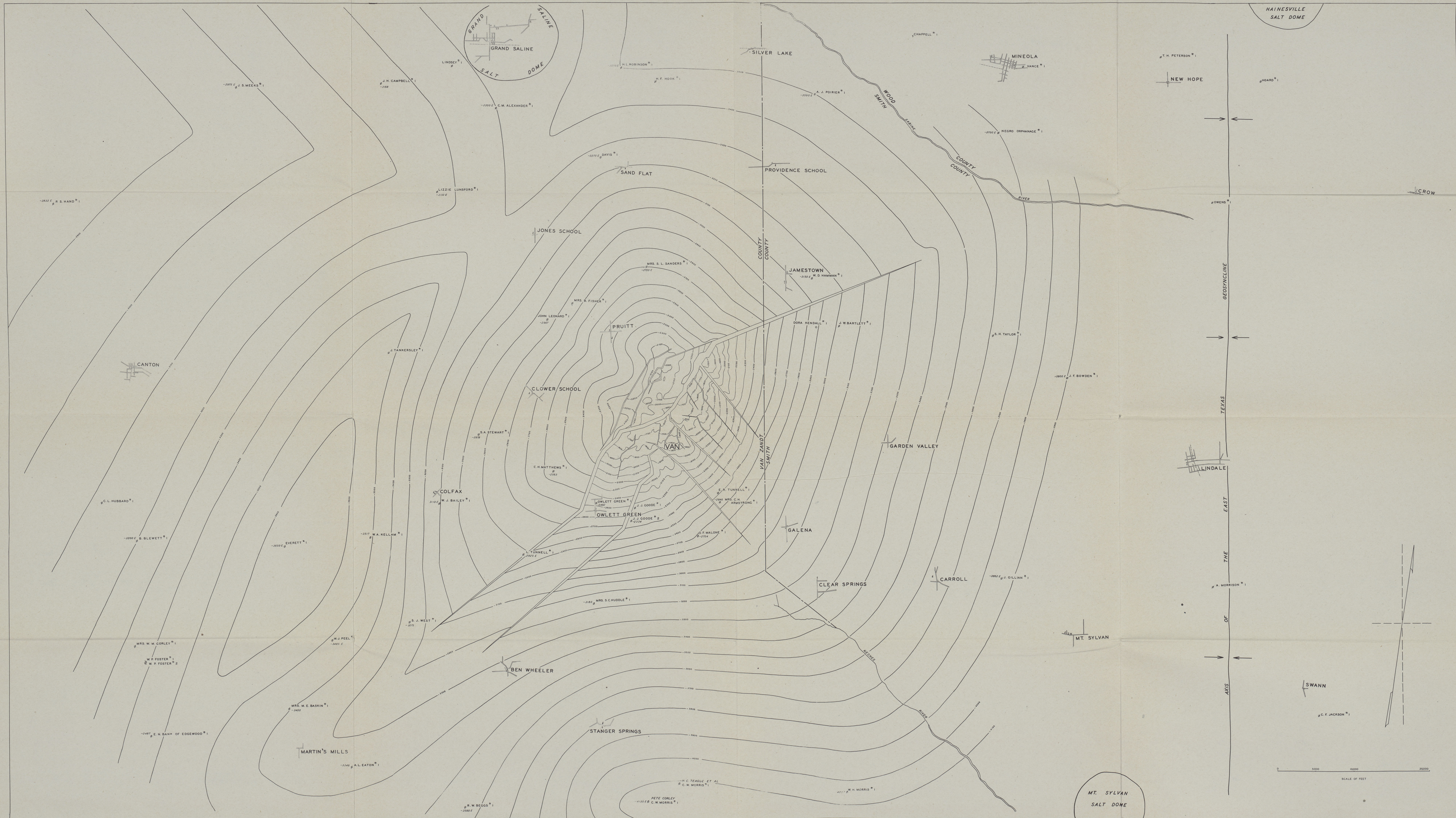


Structural map of the Van uplift contoured on top of the Pecan Gap formation. Contour interval 50 feet. Datum sea level.



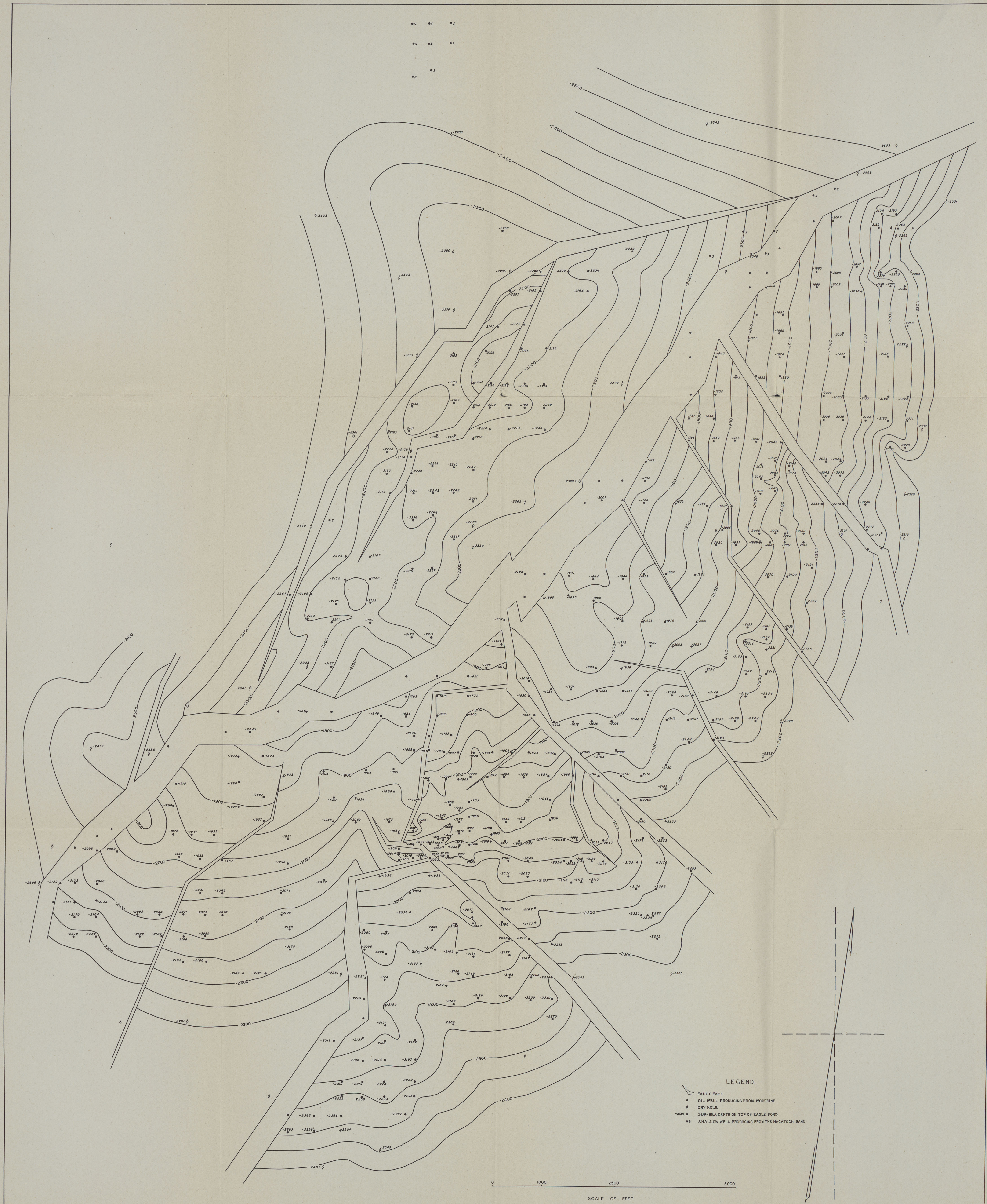
Regional structure map of the Van uplift contoured on top of the Pecan Gap formation. Contour interval 100 feet. All values are shown in feet below sea level.

Structural map of the Van uplift contoured on top of the Austin formation. Contour interval 50 feet. Datum sea level. Wells in fault faces carrying no contour values have Austin faulted out.



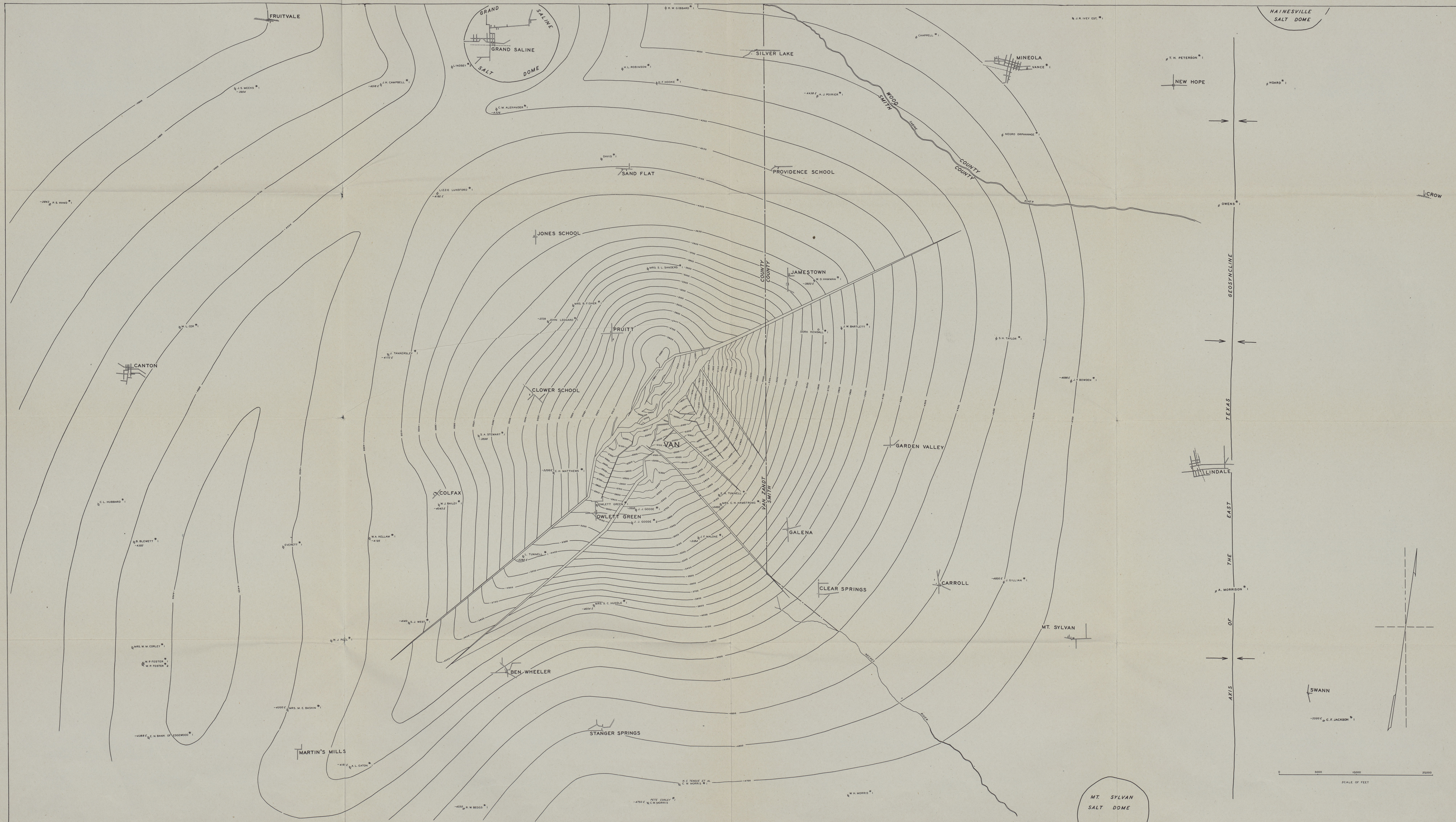
Regional structure map of the Van uplift contoured on top of the Austin formation. Contour interval 100 feet. All values are shown in feet below sea level.

17



Structural map of the Van uplift contoured on top of the Eagle Ford formation. Contour interval 50 feet. Datum sea level. Wells in fault faces carrying no contour values have Eagle Ford faulted out.

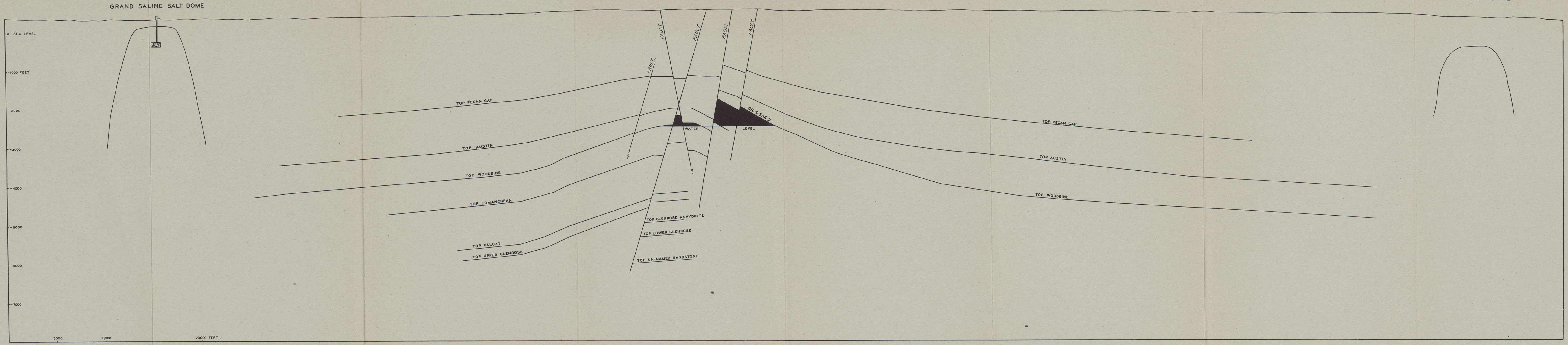
Structural map of the Van uplift contoured on top of the Woodbine formation. Contour interval 50 feet. Datum sea level.



Regional structure map of the Van uplift contoured on top of the Woodbine formation. Contour interval 100 feet. All values are shown in feet below sea level.

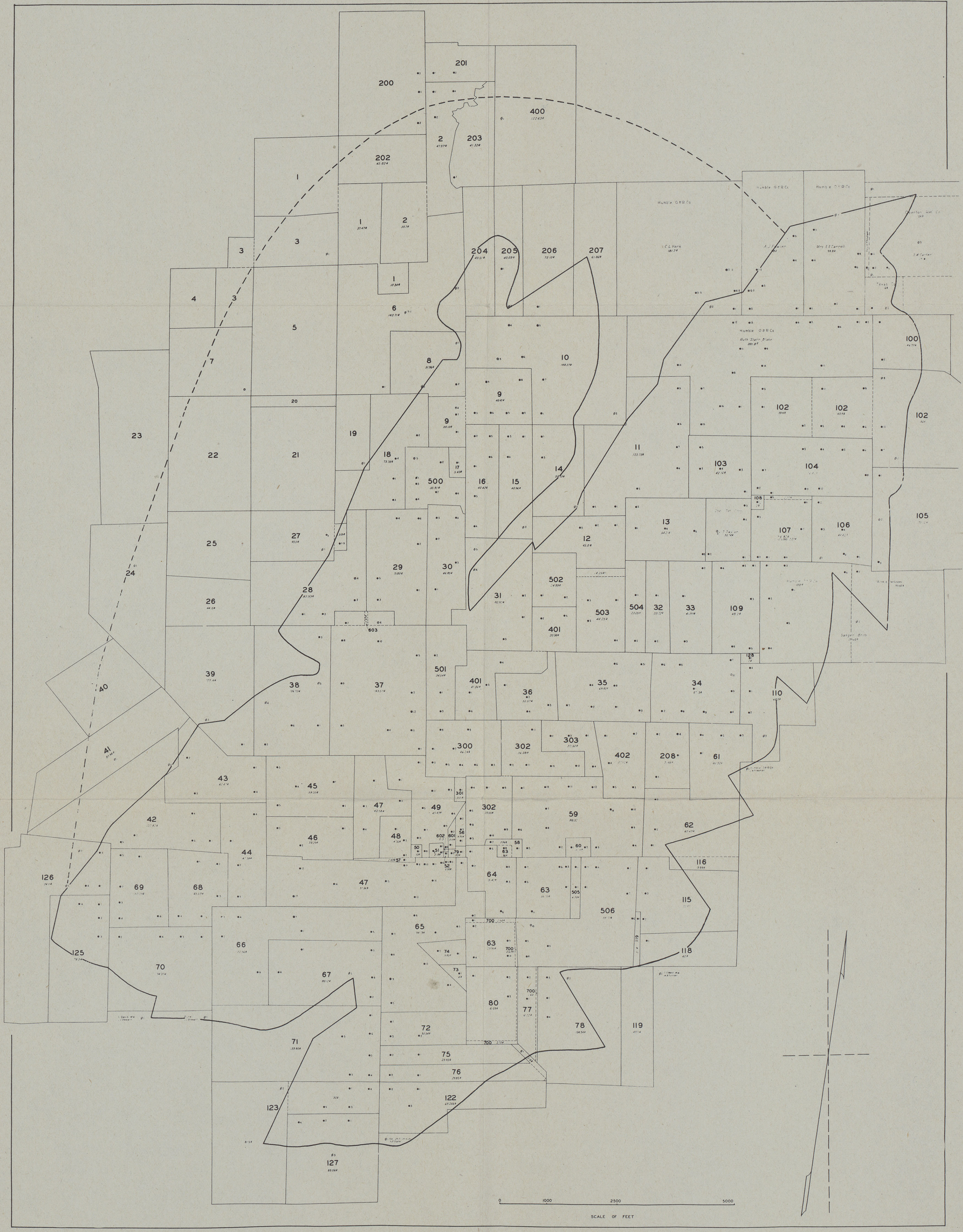
Structural map of the Van uplift contoured on top of the Woodbine formation except in faults where contouring is on the fault face. The contouring shows that part of the formation which lies above an elevation of 2,500 feet below sea level, which is the water level of the field. Contour interval 20 feet

Structural map of the Van uplift contoured on top of the Comanche except in faults where the contouring is on the fault face. The contouring shows that part of the Comanche which lies above an elevation of 2,500 feet below sea level, which is the water level of the field, and subsea values on wells reaching the Comanche north of the main fault. Contour interval 20 feet.

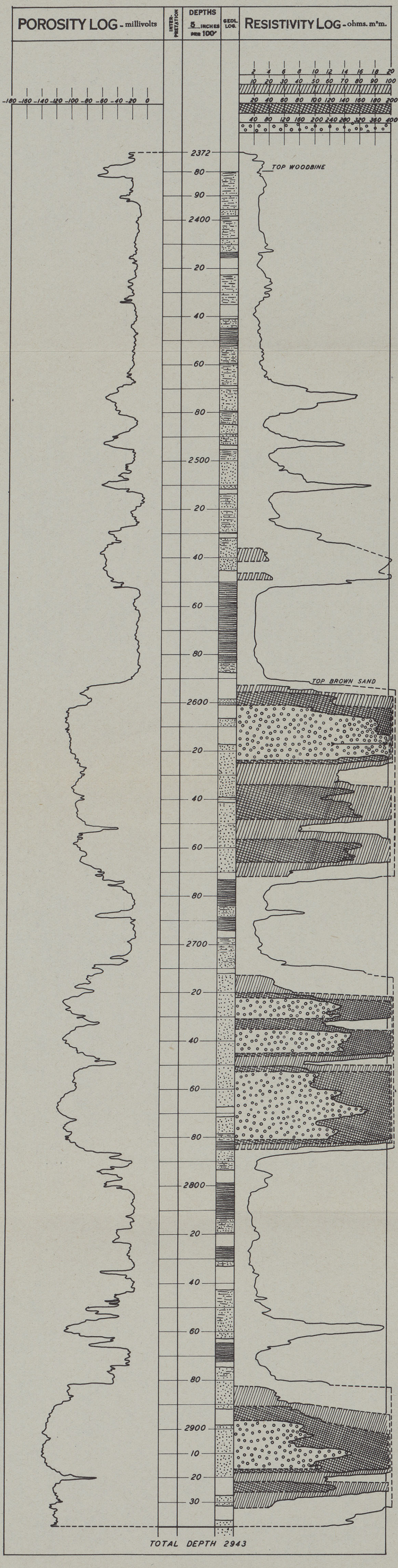


Cross section of the Van uplift from Grand Saline salt dome to Mt. Selman salt dome showing key horizons. Major faults indicated by lines cutting across formations. Water level of field as shown is the original water level at time of discovery which was 2,500 feet below sea level.

Subsurface distribution and extent of the sub-Clarksville sand in the Eagle Ford formation on the Van uplift.



Outline of the original area and the present area of accumulation of oil and gas in the Woodbine formation on the Van uplift. Outline of present accumulation of oil and gas in the Woodbine formation on the Van uplift shown by solid line. Approximate outline of original accumulation in Woodbine on north side of Van uplift shown by broken line. Original limit of accumulation and present limit of accumulation on south side of the uplift are practically identical.



Schlumberger survey record and geological log of a typical well penetrating a fairly complete section of the Woodbine formation in the Van field.

Map of the Van uplift with unitized area (Van Joint Account) outlined by stippling. Shallow wells producing from the Nacatoch in leases 2, 200, 201, and 203 are known as the Brannon district. Woodbine producing area to northeast and southwest of unitized area known as Carroll district.